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Jute—World's Paramount Bast Fiber.
Agronomy, Diseases and Pests

The Mexican Candelilla Plant

The Culture of False Hellebore

Alkaloid Yields of *Veratrum* [illegible] Influenced by Soil, Season and Other Factors

Apple Scions in Northern Grown

Peppermint and Flavoring Oil

Collection, Preservation, and Utilization of Strains of Maize

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Jute—*World's Foremost Bast Fibre.* I.[1] Botany, Agronomy, Diseases and Pests

India and Pakistan together contain over 96% of the world's acreage devoted to this crop and produce nearly 97% of the world's total supply. Two species of Corchorus are involved. The production of fibre has increased from about one million tons at the beginning of the present century to about two million tons today.

B. C. KUNDU

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INTRODUCTION

Jute is the cheapest and the most important of all textile fibres, except cotton, and is used extensively in the manufacture of different types of packaging material for various agricultural and industrial products. About two million tons of the fibre are annually produced, principally in the Indo-Pakistan subcontinent. It was a monopoly crop for India until the country was divided in 1947, when new problems developed for the industry. While India retained all the jute mills, most of the areas producing finer qualities of jute went to Pakistan. Since the partition, there has been considerable extension of acreage and increase in the production of jute in India as a result of the concerted efforts of the Government to attain self-sufficiency; and Pakistan has established some jute mills in East Bengal.

Raw jute and jute manufactures together form one of the main sources of earning foreign currency for India. Before World War II, these comprised 23.8 percent of total Indian (combined Indian Union and Pakistan) export. In 1951–52, jute manufactures accounted for 38.5 percent, in 1952–53 for 23.4 percent, and in 1953–54 for 22.08 percent of the total export from Indian Union, whereas in Pakistan, raw jute accounted for 52.5 percent of the total export in 1951–52 and 40.0 percent in 1952–53.

Several authors have described the

[1] Part II, devoted to Technology, Marketing, Production and Utilization, and containing the bibliography, will appear in the next issue of ECONOMIC BOTANY.

[2] Hereafter referred to as "J.A.R.I.".

cultivation, production and general properties of jute (14, 31, 73, 89, 110, 111, 113, 149, 155, 164, 194, 218, 239, 244–246). A number of research papers have also appeared on the botanical, agronomical and various other aspects. In 1940 a review (171) of available information was published, and since then a large amount of additional work has been done. All this information is scattered in many journals and books. In the following pages an attempt is made to bring it all together.

BOTANY

Taxonomy, Natural Distribution

Jute fibre is obtained from two cultivated species of the genus *Corchorus*, family Tiliaceae—*C. capsularis* L. and *C. olitorius* L. The genus includes about 40 species (42), distributed mostly in the tropical regions of Africa, Venezuela, the West Indies, Australia, Brazil, Bolivia, China, Ceylon, Formosa, India, Japan, Java, Malaya, Marian Islands, Mexico, Philippine Islands and Siam (126). The largest number of species is found in Africa, while only eight are in India. Of all the species, *C. capsularis* and *C. olitorius* were selected by man as economic plants.

In determining the origin of these two species, their distribution in different parts of the world is of great importance. Royle (194) was of the opinion that the ancient Greeks used to refer to a pot-herb as "Korkhoros", from which the generic name *Corchorus* is derived. The Korkhoros still cultivated in the neighbourhood of Aleppo and described by travellers in the East as a pot-herb in Egypt and Arabia as well as in Palestine is supposed to be *Corchorus olitorius*. It is small and herbaceous in the dry soil of Syria, a little taller in northern India, and attains its maximum size only in the warm moist climate of Bengal. Bentham and Mueller (19) record this species from North Australia and mention that it is common in Asia and Africa. *C. olitorius* under wild and cultivated conditions in tropical Africa was reported in 1868 (169) and later (147, 178) as indigenous to India. Watt (245, 247), on the other hand, states that it is indigenous in many parts of India and was distributed by cultivation to all tropical countries. Kundu (126) has recently discussed the origin of jute and has stated that "the primary centre of origin of *C. olitorius* is Africa and the secondary centre may be India or Indo-Burma region".

C. capsularis is not found in Africa or Australia. It was regarded by many early botanists as of Chinese origin. Watt (247) was of the opinion that *C. capsularis* was not wild in India, Malaya or China. After a careful study of the types available in the Calcutta Herbarium and from a study of types of *C. capsularis* collected by him from Bombay, Saurashtra and the district of Surguza in Madhya Pradesh, Kundu (126) stated: "*C. capsularis* is not an immigrant as stated by some authors, but its centre of origin is Indo-Burma, which according to Vavilov's map includes South China".

Nomenclature

Jute is commonly called "pat" or "nalita" in central and western regions of Bengal; "pat" or "koshta" in eastern Bengal; "pata" or "marapata" in Assam; "jhot", "jhout" or "jhuta" in Orissa; and "patua" in Bihar. The species *C. capsularis* is usually called "Tita-pat" or "Guti-pat", and *C. olitorius* is known as "Suti", "Bogi", "Tossa", "Deshi" or "Mitha" pat. In English jute is known as "Jews mallow" which is translated from the old name "Olus judiacum" (194).

There is possibly no Sanskrit name for jute. The words "pat", "patua" and "pata" have evidently been derived from the Sanskrit word "patta" which,

instead of being a specific name for jute, includes a wide range of fibres. Royle (194), however, says that jute is called " patta " in Sanskrit and " pat " in Bengali. Watt (245, 247) states that " patta ", a Sanskrit word given to jute by some writers, reappears throughout India in one form or another, being applied to a variety of fibres. In its early usage it simply meant a " shining fibre " and was probably originally given to silk, although in the Mahabharata, presents of garments are mentioned as " Patta-jam " (patta-produced) and also " Kita-jam " (insect-produced), thus relieving the word " patta " from being silk. It appears that the word " patta ", which originally referred to any kind of white lustrous fibre, later was applied to the fibre of jute.

The derivation of the word " jute " is not definitely known. Its origin from the Sanskrit word " juta " is rather unlikely. Kerr (110), after reviewing all the reports and early books of travel that refer to fibre or to rope-making in India, finds that there is no mention of the word " jute " in any of these publications until 1796. In a letter addressed to the Court of Directors of East India Company, dated 1795, Roxburgh, the botanist, then Superintendent of the Royal Botanic Garden at Sibpur, near Calcutta, first used the word " jute ". It is probably the anglicised form of the word " jhout " or " jhot " or " jhut " used by the Orya (people of Orissa, India) gardeners employed in the botanic gardens. In an article in the " Indian Antiquity " in 1901, Col. Sir R. Temple,

FIG. 1. Jute acreage in India and Pakistan in 1952. The figure for the latter should read 1,907,000.

however, stated that the name "jute" occurs in a log of a voyage made in 1746 (247). The incident mentioned by Temple carried the word back 40 years before the founding of the Royal Botanic Garden; but it is still quite likely that it came from the word "jhut".

The first commercial mention of the word "jute" is in the customs returns of the exports for 1828, when 364 cwt. of raw jute were sent to Europe.

Towards the end of the XVIII century, Roxburgh was engaged in search of a suitable substitute for European hemp in India for the manufacture of cordage for the Company's ships and as a cheap material for sacking. In 1793 he exported, for the first time, 100 tons of raw jute to England under the name of "pat" (244). By the beginning of the XIX century the word "pat" was completely superseded by "jute" in all commercial correspondence (247).

Though the two species from which jute fibre is obtained are similar in general appearance, the leaf of *C. olitorius* has a shining upper-surface, a rougher under-surface, and is almost tasteless. The leaves of *C. capsularis* contain a bitter glucoside, corchorin; hence it is often known as "Tita" (bitter) pat, whereas *C. olitorius* is "Mitha" (sweet) pat. There are, however, some non-bitter types of *C. capsularis*. The flowers of *C. olitorius* are larger than those of *C. capsularis*. The pod of *C. capsularis* is roughly globular, while that of *C. olitorius* is cylindrical. Among the *capsularis* varieties, Dhaleswari and Fuleswari and *C. capsularis* var. *oocarpus*, described by Burkill and Finlow (24), have pear-shaped or oval capsules. The seeds of *C. olitorius* are bluish-green to steel-gray in the cultivated varieties, steel-gray to black in the wild varieties. *Olitorius* seeds are smaller than those of *capsularis* which are copper-coloured. *C. olitorius* also tends to grow taller than *C. capsularis*.

Comparison of Species

Detailed comparison of the two species may be presented as follows:

	C. capsularis	*C. olitorius*
General	Five to 12 feet tall; can withstand water-logging in later stages; herbaceous annual, 3 to 5 months duration, depending on time of sowing.	Five to 15 feet tall; cannot normally withstand water-logging; herbaceous annual, 4 to 5 months duration, depending on time of sowing; flowers prematurely if sown very early.
Stem	Cylindrical, green or dull coppery red to pink; periderm in the basal portions in later stages.	Cylindrical, green, light red or dark red; shades of colour fewer than in *capsularis*; no periderm but lenticels in later stages.
Branching habit	Branched or unbranched; axillary buds may or may not develop into branches.	Branched, but branches normally develop less vigorously.
Leaves	Glabrous, 5 to 13 cm. × 2.5 to 8.2 cm., ovate-oblong, acuminate, coarsely toothed, lowermost pair of serrations enlarged and end in hairy appendages.	Glabrous, 7 to 18 cm. × 4 to 8 cm., oblong, acuminate, coarsely toothed, lowermost pair of serrations more enlarged than in *capsularis* and hairy appendages longer.
	Petiole 4 to 8 cm.; varies from green to pink in different varieties.	Petiole 4 to 9 cm.; varies from green to dark red.
	Stipules 0.5 to 2 cm. or more; foliaceous in some varieties; tip coloured except in the full green types; base coloured or green.	Stipules 0.5 to 1.5 cm. or slightly more; tip coloured or green; base coloured except in the full green types.
Flowers	Small, generally in extra axillary cymes in groups of 2 to 5 or more; 0.3 to 0.5 cm. in length and 0.5 to 0.6 cm. in breadth; sepals 5, coloured or green;	Generally in extra axillary cymes in groups of 2 to 5, about 1 cm. in length, 2 to 2½ times the size of those of *capsularis*; sepals 5 or 6, coloured or green,

	petals 5, yellow or pale yellow; stamens 20 to 30; anther yellow or pale yellow; ovary rounded, 5-carpelled, syncarpous; ovules axile, usually 10 in each loculus in two rows, giving about 50 ovules in each ovary; style 2 to 4 mm.; stigma 2- to 3-fid, pubescent.	tips prolonged in flower buds; petals 5 or 6, yellow, entire or split, stamens 30 to 60; anthers yellow; ovary elongated, 5-, rarely 6-carpelled, syncarpous; ovules axile, usually 40 in each loculus in 1 row giving about 200 ovules in each ovary; style 3 to 5 mm.; stigma globular, entire, pubescent.
Anthesis	One to two hours after sunrise.	An hour or less before sunrise.
Capsule	Rounded, 1 to 1.5 cm. in diameter, wrinkled, rarely smooth, muricate, 5-locular; seeds 7 to 10 in two rows in each loculus, without transverse partitions, 35 to 50 in each fruit.	Elongated, 6 to 10 cm. long, 0.3 to 0.8 cm. in diameter, ridged lengthwise, 5- to 6-locular; seeds 25 to 40 in single row in each loculus, with transverse partitions between each seed and 140 to 200 in each fruit.
Seed	Small, chocolate brown, 4- to 5-faced, about 300 per gram.	Smaller than those of *capsularis*, bluish green to steel gray or even black; about 500 per gram.

The two species differ in the quality of fibre they yield. Fibre of *olitorius* is frequently finer, softer, stronger and more lustrous than that of *capsularis*. The fibre of *capsularis* is ordinarily whitish and therefore it is called "white jute" by the trade. *Olitorius* fibre has either yellowish, reddish or a grayish shade, depending upon the nature of the retting water.

Within each of these species are well defined forms, or races, based on various characters, e.g., pigmentation, pod shape and size, petal and anther colour, stipule character, seed-coat colour, taste of leaves, earliness and lateness, yield and quality of fibre (23, 82, 83, 172, 173).

The forms of *C. capsularis* are more numerous than those of *C. olitorius*. After making a thorough study of morphological and cultural characteristics, Burkill and Finlow (23) concluded that there were 33 distinct *capsularis* races and five *olitorius* races; three of these are grown as vegetables. Studies at J.A.R.I. indicate more than 50 forms of *capsularis* and at least eight of *olitorius*, excluding the wild types of both. On general morphological characters and yield, Chaudhuri (31) described the races of *capsularis* and *olitorius* occurring in the major jute-growing districts.

The colour of stem, petiole, leaf and pod varies in the different forms. It may be green, pink, red or purple, but this has no relation with the colour of the fibre. Differences in the pattern of colour, due to anthocyanin pigments in the cultivated species of *Corchorus*, form a striking feature of the jute crop. By this character alone many of the strains and cultures can be easily identified.

The root systems of the two species differ. In clayey soil the tap root grows to a depth of ten to 12 inches in *C. capsularis*, 17 to 21 inches in *C. olitorius*. In sandy-loam soils the tap root of *C. capsularis* grows to a length of 20 to 28 inches, that of *C. olitorius* to 25 to 32 inches. Secondary roots in *capsularis* are more numerous, superficial and bushy, while in *olitorius* they are well developed and more deeply penetrating.

The nature and range of flowering period also differ in the two species. Flowering in *C. olitorius* is distributed in periodic flushes over a range of about ten weeks; in *C. capsularis* the sequence of flush lasts over a shorter period of four to six weeks.

Agriculturally the distinction between early and late forms is very important. For low lying areas which are subject to early floods, early maturing forms are required. Fanduk, Dhaleswari, Fuleswari and Deshi or Jalpaiguri are some of the early *capsularis* forms. "Small early maturing races of *C. capsularis*

known as 'Aussa' (early) or 'Chotta pat' (small jute) used to be cultivated in Northwest Mymensingh of East Pakistan. The average height of these races was probably not more than seven feet, and they produced a type of fibre for which Sarisabari (Mymensingh, east Pakistan) was well known. However, the price obtained for this comparatively short fibre was not sufficient to compensate for the loss of yield as compared with taller races grown on the opposite banks of the river Brahmaputtra in Pabna district (East Pakistan) and the latter have now largely replaced the former" (73).

Olitorius jute does not stand waterlogged conditions as much as *capsularis* jute, and so it is grown on higher lands only. *Capsularis* jute can, however, be grown on high and low lands. *C. capsularis* may be sown at any time after the middle of February, and with earlier sowings better crops are obtained. *C. olitorius* should not normally be sown before the middle of April, as in early sowings it flowers prematurely and often branches considerably.

Cytology

The first report (11) of seven as the haploid chromosome number in *C. capsularis*, *C. olitorius* and *C. acutangulus* was confirmed (55, 159) in several types of *C. capsularis*. Seven haploid chromosomes in *C. tridens*, *C. trilocularis* and *C. fascicularis*, and hypo- and hyperploidy in all the Indian species have also been detected (57, 180, 205). Kundu (128) and Datta (57) reported the same number for *C. tridens* and *C. trilocularis*. Mukherjee (156) confirmed this. *C. siliquosus* is a natural polyploid having $n = 14$.

Meiotic lability was first reported in both species of jute (56) and later in *C. fascicularis* (180). The latter observed this behaviour in other species of *Corchorus* and considered it to be a characteristic of the genus.

Nandi (160) described a trisomic mutant in *C. capsularis* which showed dimorphic gametes with seven and eight chromosomes. Ghose and Datta (80) described the morphology of V_2 and V_3 mutants. V_2 was a gene mutant having $2n = 14$; and V_3, an aberrant branch of a normal diploid, the branch being trisome, having $2n + 1 = 15$.

Secondary association in *C. capsularis* (160) has been challenged (77). Further work on this aspect is in progress at J.A.R.I.

Normal cytological behaviour in pollen development reported in both *C. capsularis* and *C. olitorius* (13) was later confirmed (90). The development of embryo-sac was normal and fertilization porogamous (12).

Genetics

Studies on the inheritance of different characters have been carried out for a number of years. The results, briefly, have been as follows:

Anthocyanin Pigmentation. Burkill and Finlow (23) recognised four patterns of colour variation in *capsularis:*

(*a*) Red stem, red petioles, red fruits, bright yellow flowers.
(*b*) Green stem, rosy petioles, rosy fruits, red on the outside of flower buds, bright yellow flowers.
(*c*) Green stem, green petioles, green fruits, no red on the outside of flower buds, bright yellow flowers.
(*d*) Green stem, green petioles, green fruits, no red on the outside of flower buds, pale yellow flowers.

They observed that some of the patterns show intermediate shades of pigment, and felt that the constancy of these combinations suggests interesting Mendelian experiments.

Finlow and Burkill (74) worked out the inheritance of pigment and reported

a single gene difference between red and green, red being dominant. Patel and Ghose (171) examined their data and found that more than one gene is involved in the production of red.

The differences in the patterns of anthocyanin pigmentation in the cultivated varieties of *Corchorus* are very helpful in the identification of many strains. Further work has shown that in *C. capsularis* the anthocyanin pigmentation, which ranges in intensity from pure green to dark-red, is the result of the interaction of three genes:

C—The chromogen gene, fundamental for the production of pigmentation (C, pigmented; c, green)

A—Pigment-producing gene, with no visible effect on the plant body except in the presence of dominant chromogen gene C; present in multiple allelomorphic series A^D-A^R-A^L-A-a.

R—Pigment-reducing gene, the effect of which is most marked on the stem (R, reduction; r, no reduction).

The pigmentation patterns fall into three groups: (*a*) full-greens with combinations of different allelomorphs of A with R-r but with recessive chromogen gene c; (*b*) green-pigmented types with different allelmorphs of A with dominant C and R; and (*c*) red group with the allelomorphs of A with dominant C and recessive r. All the five possible green-pigmented types and four of the red types, besides six of the ten possible full-green types, have been isolated (53, 82, 172).

Anthocyanin pigmentation in *C. olitorius* is controlled by a single gene in allelomorphic series $A^D{}_o$-$A^R{}_o$-a_o (Deep red–Red-Green). Thus the green type in *C. olitorius* is the result of a recessive anthocyanin allele, whereas in *C. capsularis*, the green type is due to the recessive chromogen gene, and any particular green type is dependent on the anthocyanin multiple allele and the reducing allele carried by it (82, 172).

Pod-shape. In crosses between the oval-pod variety Deodhali and a round-pod variety D154, the pods of the F_1's were intermediate, the base being less elongated than in Deodhali. The F_2 families segregated in a simple monogenic ratio. The gene for pod-shape, G, was linked with the gene for anthocyanin pigmentation, C, with eight percent crossing-over (78).

Branching habit. Branching habit in *capsularis* is controlled by a single gene, Br–br (branched–non-branched). All Indian *capsularis* types are branched, while the recessive gene, br, occurs only in some foreign *capsularis* types (173).

Stipule character. In some foreign *capsularis* types, like Halmahera, the stipule is foliaceous, in marked contrast with the stipules in Indian *capsularis*. The character is controlled by a single factor pair, Sfl–sfl (173).

Bitter taste. Monogenic inheritance of bitter taste in *C. capsularis*, Tb–tb (bitter–non-bitter), has been established. The gene is linked with Br, the factor for branching, with a crossing-over percentage of 22.2; there is no evidence of linkage with the allelomorphic series of the anthocyanin genes (83).

Undulate leaf. The undulate leaf type when crossed with normal flat leaf type gave intermediate F_1's. In F_2 they segregated in a monogenic ratio, the undulate type being dominant (undulate—W, normal—w) (52).

Corolla colour. Corolla colour in *capsularis* jute is either yellow or pale yellow and is controlled by a single factor pair, Pp–py (yellow-pale). In Indian *olitorius* no pale yellow types have been found, but in a foreign variety, light-yellow corolla and light-yellow anther were noticed, and the factor pair controlling their colour was designated Py_o–py_o (yel-

low–light-yellow). The corolla colour gene is not linked with any of the anthocyanin genes (173).

Anther colour. Monogenic inheritance has been established for anther colour in *C. capsularis*. The light yellow anther colour is recessive to yellow anther and is completely linked with pale-yellow petal (83).

Seed-coat colour. The seed of cultivated *olitorius* is leek green, while in wild *olitorius* the seed is dull black. Inheritance of seed-coat colour is governed by a single factor, Gr–gr (dull–leek green) (173).

In *capsularis* the gene for oval pod shape is linked with the chromogen recessive allele c, with eight percent crossing-over. The factor for bitterness, Tb, is linked with the gene for branching, Br, with a cross-over value of 22.2 percent. The anthocyanin multiple allelomorphs and the pigment reducer gene are on different chromosomes. Anther and corolla colour characters are not linked with any of these and are situated on a fifth chromosome. Thus, of the seven chromosomes in *C. capsularis*, only two have linked genes on them, and independent segregation has been noticed in all the other characters.

Breeding

The necessity for genetic improvement of jute was felt by the Government of Bengal as early as 1900 when a Committee was set up to devise ways and means toward that end. The Committee recommended that attempts be made to evolve, by selection or otherwise, types having higher yield and better quality. Mr. R. S. Finlow, who was appointed fibre expert to the Government, and his assistant, Mr. N. C. Basu, worked successfully on all aspects of the production of jute for nearly 25 years (73, 171, 185, 186). As a result of their work, two high-yielding strains, D154 (*C. capsularis*) and C.G. (*C. olitorius*), were obtained by pure line selection and distributed. For many years they were the standard strains (2, 171).

The Royal Commission on Agriculture, set up by the Government of India in their report published in 1928, recommended the establishment of a Central Jute Committee under the Government of India for taking up intensive research work on jute from the field to the factory. The Indian Central Jute Committee was constituted in 1936 by a resolution of the Government of India in the Department of Education, Health and Lands. The functions of the Committee are, broadly, to pursue research on the agronomy, technology, economy and marketing aspects of jute, the improvement of crop forecasting, and the production, testing and distribution of improved seeds. The Jute Agricultural Research Laboratories were established in Dacca in 1938, where research work on all aspects of the improvement of the crop and of the fibre was undertaken. With the partition of India in 1947, the Jute Agricultural Research Laboratories at Dacca were completely disorganised. The next year the new Jute Agricultural Research Institute was started in the Indian Union. Some improved *capsularis* and *olitorius* types have been evolved which are superior to the previously developed improved strains, and they have been released for multiplication.

The two species of jute are grown under varying conditions, and a breeder is confronted by various obstacles in labelling, recording, observation, harvesting, etc. In order to overcome these difficulties, a technique for selection and handling of breeding material was developed (81). A plan of field experiments, particularly with reference to size and shape of plots and blocks and border effect in jute trials, was also worked out. Standard error percent per plot decreased steadily with increasing plot size, but for the same size, plots which were

square or near square generally recorded lower standard errors than long and narrow plots. Square and compact blocks proved more effective than long and narrow blocks. For both varietal and manurial trials, borders were necessary to avoid biased comparison, and a two-foot border was considered sufficient (84).

in the buds, self-fertilization was the rule and cross-pollination was very rare. Ghose and Das Gupta (79) have shown that in *C. capsularis* natural cross-pollination is two to five percent and sometimes more; in *C. olitorius*, where the flowers are larger and remain open longer, the percentage averages 13.

As jute is a bast fibre crop and is normally harvested long before the seeds mature, both fibre of good quality and seed cannot be obtained from the same plant. Since a selected plant has to be kept for seed and its fibre content cannot be determined directly, it is necessary to select plants on the basis of morphological characters which influence the yield of fibre. Two such characters in jute are the height and thickness of

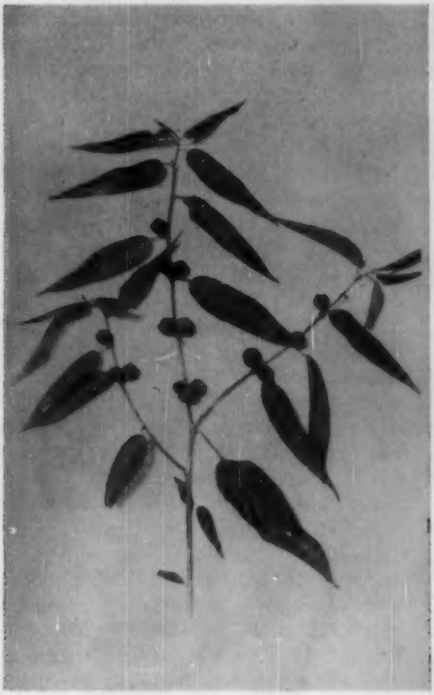

FIG. 2. *Corchorus capsularis*

FIG. 3. *Corchorus olitorius.*

In connection with their studies on the mode of inheritance of red colour in *C. capsularis*, Finlow and Burkill (74) concluded that jute is normally self-pollinated, though a small percentage of cross-pollination, not more than two percent under the most favourable circumstances, took place. Others (92) stated that in both *C. capsularis* and *C. olitorius*, as the anthers burst and shed pollen

the plant, the correlation coefficient of these two with the fibre yield being +0.761 and +0.914, respectively. The greater the height and the greater the thickness of the stem, the larger is the outturn of fibre (81).

Two main considerations in the improvement of jute are the yield and quality of the fibre, both of which should progress simultaneously. Jute plants generally require a fairly long vegetative period in order to attain good height and stem thickness; hence late maturing types usually yield higher, although they are reported to suffer somewhat in quality.

Colour, lustre and softness are concomitant with good quality of fibre. Early maturing types of *capsularis*, like Fanduk, give superior fibre, but plants of such early types with short vegetative period are usually thin-stemmed and not tall; consequently they yield low.

With such divergent considerations as yield and quality, improvement in one direction may mean retrogression in the other. Research work for the development of strains with high yield and better quality of fibre has to be carefully followed in such a manner that advance in one direction will not mean undue sacrifice in the other. At J.A.R.I. work has been carried out on these lines, and some promising high-yielding strains with superior quality of fibre have been obtained. These varieties, along with other improved strains, were tried out for three years in field trials at the Institute, and the results of the combined analysis are given in Table I (3E).

Some of the improved strains of jute are:

C. capsularis

D154: Produced by the Bengal Department of Agriculture[3] in 1919 after about 15 years of research. It is a branching type with a long vegetative period, takes a little over four months to mature and gives high yield. It is green-coppery-red with all parts of the stem green; upper surface of the petiole, tips of stipules and tips of basal serrations of leaves dull coppery-red; lamina of leaf and lower surface of petiole green. Mature plants show coppery-red on apical regions of stem, outer-surface of calyx and pods.

JRC-212: Evolved by J.A.R.I. Matures about a week earlier than D154 and on the average yields about 11 percent higher. Quality of fibre considered very good. Full green type with all parts of the plant, at all stages of growth, green. Among *capsularis* strains this is, at present, the highest yielder.

JRC-321: Early quick growing type of J.A.R.I. Matures two to three weeks earlier than D154. Stem uniformly coppery-red except at the tip, where it is green. Rest of the plant, upper surface of petioles, tips of stipules and tips of basal serrations of leaves correspond in colour to those of D154 and are dull coppery-red. Flower buds and pods also red. Fibre of very good quality. Very suitable for 'double-cropped (jute-paddy) areas and flooded regions, especially of Assam, North Bengal (Sub-Himalayan regions), and for sub-montane regions of Bihar and Uttar Pradesh where the crop is usually harvested early. In trials conducted in the cultivators' fields of these areas it has almost always given higher yield than other improved strains. Under highland conditions, however, its yield is less.

JRC-13: Developed by J.A.R.I., matures two to three days later than JRC-212 and yields about four percent more than the standard variety D154. Fibre is slightly better than that of D154. Full green type with all parts, at all stages of growth, green.

JRC-1: Evolved by J.A.R.I. from a type of Assam, and in trials at the In-

[3] Referred to hereafter as " B.D.A.".

stitute gave a yield about four percent higher than that of D154, though under cultivators' conditions it sometimes yields less. In morphological characters it resembles D154 and matures about the same time.

red pigment in the stem also. Susceptible to stem-rot.

Fanduk: Early type bred by B.D.A. Resembles D154 during vegetative period. Flowers four to six weeks earlier and is thus suitable for double

TABLE I

Variety	Yield * per acre in maunds	Percent on control	Mean No. of days from sowing to 1st flower	Quality ratio **		
				1950	1951	1952
			Capsularis			
JRC-212	27.25	110.77	109	110 ± 2.0	104 ± 1.4	107 ± 2.4
JRC-13	25.53	103.78	110	85 ± 0.5	102 ± 1.5	100 ± 1.8
JRC-1	25.49	103.62	112	82 ± 0.9	91 ± 1.4	100 ± 1.3
Orissa 6J	24.86	101.06	111	113 ± 1.3	92 ± 1.4	95 ± 1.3
D154	24.60	100.00	114	93 ± 1.0	91 ± 1.4	91 ± 0.9
Jap Red	22.93	93.21	117	126 ± 1.2	107 ± 1.4	87 ± 1.0
Fanduk	20.10	81.71	87	122 ± 1.5	103 ± 1.0	100 ± 1.4
JRC-321	19.53	79.39	99	106 ± 1.1	104 ± 1.4	112 ± 1.0
P	0.01					
C.D.	1.77					
S.E.%	2.00					
			Olitorius			
JRO-632	24.03	140.36	109	88 ± 0.8	79 ± 1.7	108 ± 1.1
JRO-753	23.84	139.25	110	104 ± 1.4	74 ± 1.5	98 ± 1.9
JRO-620	20.99	122.61	101	133 ± 1.2	89 ± 1.3	100 ± 1.8
C.G.	17.12	100.00	99	109 ± 1.0	80 ± 1.3	94 ± 1.2
R26	15.80	92.29	106	89 ± 0.8	89 ± 2.3	110 ± 2.1
P	0.01					
C.D.	1.18					
S.E.%	1.50					

* Maund = 82.29 lb.

** Quality ratio is a measure of the strength of fibre. For details see Part II. Technology.

Orissa 6J: Evolved by J.A.R.I. Performs well in Orissa. In trials conducted at the Institute, it yielded two to three percent higher than the standard strain D154 and matures about the same time as D154. Similar to D154 also in pigmentation and morphological characters.

Jap Red: Selected by J.A.R.I. from foreign material. Marked by absence of branches in earlier stages of growth. Produces branches only with approach of maturity. Yield is slightly lower than that of D154, but the quality of fibre is much better. Petioles, flower buds and pods coppery-red as in D154, from which it differs in having coppery-

and triple cropping. Yields less than D154 but the quality of fibre is much better.

C. olitorius

C.G., or Chinsurah Green, was evolved by B.D.A. and released at about the same time as D154. Tall, full green type, takes about three and a half months to mature, though among the cultivated types of *olitorius*, it is one of the earliest. Seeds bluish-green.

JRO-632: High yielding, sparsely branched, full green type evolved by J.A.R.I. Taller than C.G. and, though it takes only about ten days more to

mature, yields on the average 30 percent higher and gives fibre of better quality. Seeds steel-gray, thus differ from those of C.G.

JRO-753: Full green strain selected by J.A.R.I. Similar in appearance to JRO-632; it yields only two percent less. In fibre quality similar to C.G. Seeds steel-gray.

JRO-620: Light-red strain evolved by J.A.R.I. Stem, upper surface of petiole, veins on under surface of leaves, edges of serrations of leaves, stipules, flower buds and pods, all light-red, but the lamina is green. Matures about the same time as C.G. but yields about 20 percent higher, giving fibre of excellent quality. Seeds steel-gray, but the shade of colour is slightly different from that of JRO-632 and JRO-753.

There is much scope for improvement in yield and quality of jute if the characters of the two species could be combined through hybridization. Unfortunately, the two species do not cross with each other. Finlow stated that no difficulty was experienced in hybridising races of *C. capsularis* amongst themselves or races of *C. olitorius* amongst themselves, but in spite of numerous attempts, viable seeds were never obtained from crosses between the two species, though in some of the crosses seed pods were formed and matured, but seeds always failed to germinate (67, 72, 73). Over 1000 interspecific crosses were attempted at Dacca during the period 1939–43. A number of crosses obtained by the ordinary method of making straight crosses resulted in failure. Other methods, e.g., application of stigma paste of the male parent to the stigma of the female parent, reducing the length of the style in *olitorius* mothers by pruning, and use of mixed pollen, were all tried without success. Since the setting up of J.A.R.I., every year a number of interspecific crosses have been attempted between the two species in the diploid and tetraploid states and their combinations, but in vain.

An effort has been made to determine whether the incompatibility between the two species resides in the stigma, style or ovule, or whether it is attributable to genic differences. Srinath and Kundu (238) concluded that it is not a result of any retardation in growth of the pollen tube within the stylar tissue in either direction.

To overcome the incompatibility, seeds of both species were treated with colchicine to raise tetraploid plants which might be hybridized. Tetraploids were obtained in *C. capsularis* (159, 179) but not in *C. olitorius* (179). Bhaduri and Chakravarti (20) obtained tetraploids in both species and made a large number of reciprocal crosses between the auto-tetraploid forms; they even expected a few fertile amphidiploids among the tetraploid hybrids. Tetraploidy was also achieved in *C. capsularis* by treating seeds with a cheap fungicide, benzene hexachloride, commonly known as Gammexane (181). Since 1949, colchicine-induced polyploids of both species have been under study at J.A.R.I. *Capsularis* polyploids do not differ from those obtained earlier by Rao et al. The *olitorius* ones are shorter than the normal diploids but the base diameter is slightly more. Yield of *olitorius* polyploids is significantly lower (3E-F). Sectorial chimeras were also observed. Interspecific crosses between the tetraploids of the two species and between the tetraploids and diploids in different directions have so far failed to yield viable seeds.

By treating seeds of the two species with different doses of X-ray, Kundu (119, 121) did not find any mutations, although various structural aberrations were reported by him. The variations in plants raised from soaked seeds were more than in those from dry seeds. A

preliminary account of a mutant plant with a height of 17 feet and basal diameter of 1.9 inches from X-irradiated seeds was given by Jacob (102, 103).

Anatomy

The gross anatomy of the jute stem has been described by various authors (144, 148, 164, 174, 196, 248); based on developmental studies, Kundu (116), for the first time, described the origin and structure of the fibres. They develop in the bark of the stem, in wedge-shaped groups, each group having alternate patches of sclerenchyma fibres and soft tissue. The outermost layer of fibre is developed from the protophloem, and all the inner layers, forming part of the secondary phloem, are developed by the activity of the cambium. Each pyramidal wedge of the secondary phloem has a broad basal region and tapers outwards. At the basal region of the plant are usually eight to 24 layers of fibre bundles (ten to 24 in *C. capsularis*, eight to 19 in *C. olitorius*) in radial depth, alternating with an equivalent number of soft tissue layers. The number and size of fibre bundles in the phloem wedge are the results of cambial activity and are dependent on the growth and vigour of the plant.

Secondary wood developed by the cambium forms a thick zone and occupies the greater part of the radial depth. The number of vessels with wide lumen in the secondary xylem is very small compared to the number of smaller lignified elements, mainly fibres and wood parenchyma. The pith in *C. olitorius* collapses early so that the mature stem has a hollow region in the centre. In *C. capsularis* the pith persists and consists of large thin-walled cells.

The wood of *C. capsularis* differs from that of *C. olitorius* in having less pronounced growth zones, cell walls of the different wood elements being comparatively less thickened; vessels occur singly and are more diffused. In *C. olitorious* the cell walls of wood elements are more thickened; vessels usually occur in groups of two, three or rarely more, occasionally singly. The wood of *C. olitorius* becomes harder than that of *C. capsularis* on account of the presence of thicker wood elements. As a result, more difficulty is experienced in harvesting *olitorius* (54).

The fibre bundles vary greatly in shape and size. They may be more or less square, rectangular or elongated radially. In *C. olitorius* the radially elongated fibre bundles occur more frequently and form a striking feature of this species. The number of fibre cells in the bundle is very variable in both, although in general it is lower in *C. capsularis*.

The commercially important fibres are the secondary phloem or phloic fibres, i.e., those developed by the cambium. The outermost layer of fibres is derived from the protophloem and usually does not exceed ten percent by weight of the total fibre content of the plant (116, 118).

In surface view the fibre bundles which form definite strands are arranged in the form of a network. In tangential longitudinal sections, passing through the fibrous areas of the stem from outside to the interior, the outer fibre groups (bundles) form a loose network with intervening patches of wide oval ray tissues, and the inner ones form a closer network with much narrower ray tissues in the meshes. The degree of meshiness increases not only from the exterior to the interior but also from the top to the base and is more in *C. capsularis* than in *C. olitorius*. This depends on the activity of the cambium, formation of the secondary rays and the frequency of division and reunion of the fibre bundles (117).

The cells which make up the fibre strands or patches are elongated in the

direction of the stem axis with pointed or tapering ends and appear more or less polygonal in outline with well defined angles in cross section. Each fibre cell is known as an " ultimate fibre " and can be easily separated by macerating the fibre bundles in different chemicals. They vary from 500 to 6500 μ in length and from ten to 30 μ in diameter. The average length of the fibres of the outer group developed from the protophloem is 3.2 mm., and that of the fibres of the inner group is 1.5 mm., but there is very little difference in diameter. In jute, as in *Cannabis sativa*, the longest fibre cells (ultimate fibres) occur in the longest internodes (116). Fibre cells between four mm. and six mm. in length are common in the longer internodes. The fibre cells of jute are much shorter than those of cotton, linen, hemp or wool. For spinning by ordinary methods, the ultimate fibres should normally be fairly long and the length-breadth ratio should be of the order of 1000–2000 (240). In jute this ratio is on the average only about 120 (Kundu, Rao and Saha, unpub.). Some, however, have placed it at 150. Thus the use of jute is limited to coarse fabrics.

The ultimate fibres of jute are cemented together by an isotropic non-cellulosic intercellular substance which forms the middle lamella between the cells.

The walls are thick and lignified, and, except for occasional transverse cracks, are relatively smooth and unmarked. The lumen is as wide as the cell walls, but shows characteristic constrictions at irregular intervals, and sometimes is even completely closed by uneven thickening of the cell wall.

The ultimate fibres have not been studied in detail as in cotton. In connection with studies on the relation of the structure of jute and *Hibiscus* fibres with quality, Rao and Kundu (183) have observed that the fibre of *C. olitorius* is superior to that of *C. capsularis* and that the fibre of *H. cannabinus* is superior to that of *H. sabdariffa* var. *altissima*. The number of ultimate fibres in a cross section of a fibre strand is more in *C. olitorius* and *H. cannabinus* than in *C. capsularis* and *H. sabdariffa* var. *altissima*, respectively.

Superior quality of fibre is obtained when the crop is harvested at bud stage, and with the approach of maturity, fibre quality is gradually reduced. With maturity of the plant, periderm formation also increases and this hinders proper retting. The adherent periderm lowers the quality of the fibre (174) by increasing the nitrogen, fat and wax content (28). Study of the length, breadth and lumen of the ultimate fibres has indicated that the breadth and size of lumen attain their maximum at the bud stage. This appears to be due to natural moisture content of the plant. With maturity, the plants are gradually desiccated, and this leads to shrinkage of the fibres. There is, however, no increase in the average thickness of the wall except in some fibres of the outermost layers (182).

Bud meristems, invariably present in every leaf of branching plants, are absent from non-branching plants as a result of early vacuolation. In the non-branching types some branches develop sporadically, but their rate of growth is slower than the normal (140, 141).

Physiology

Photoperiodism. Both species of jute consist of typical short-day plants. The transition from vegetative to reproductive phases is influenced mainly by the daily light period. Long photo-periods prolong the vegetative stage; and the plants flower only with the approach of short days in late August and early September, irrespective of the sowing date. In all photoperiods between ten and twelve hours, flowering is induced in

about 30 days; the critical light period seems to be about 12½ hours, above which flowering is retarded. *C. olitorius* is more responsive to short light periods than *C. capsularis* (220, 222–225, 227–229).

The effective factor for early flowering in off-season sowing is the prevailing short photoperiod; temperature and water supply have little influence (220).

Vernalization. Response to pre-sowing cold treatment of seeds is manifested by delayed germination and production of more green pigment in the leaves and more vigorous growth in the early stages; there is no significant effect on the date of flowering (104). Sengupta (228) reports that there was some earliness of flowering and fruiting as a result of vernalization. The differences in the vegetative growth with reference to the total heights reached, daily increase in height and mean length of each internode caused by vernalization were not statistically significant (227).

Water Requirements and Osmotic Values. Both species require plenty of water and humid conditions for normal growth, but growth is adversely affected by water-logged conditions. The water requirement and the moisture economy in the two species are different (35, 36). Drought resistance investigations have shown that in early stages of growth, *capsularis* can withstand natural drought better than *olitorius*. Resistance to drought can be induced by alternate soaking and drying of seed before sowing. The response to this kind of treatment also varies in the two species, *capsularis* showing greater resistance to drought than *olitorius* (3E).

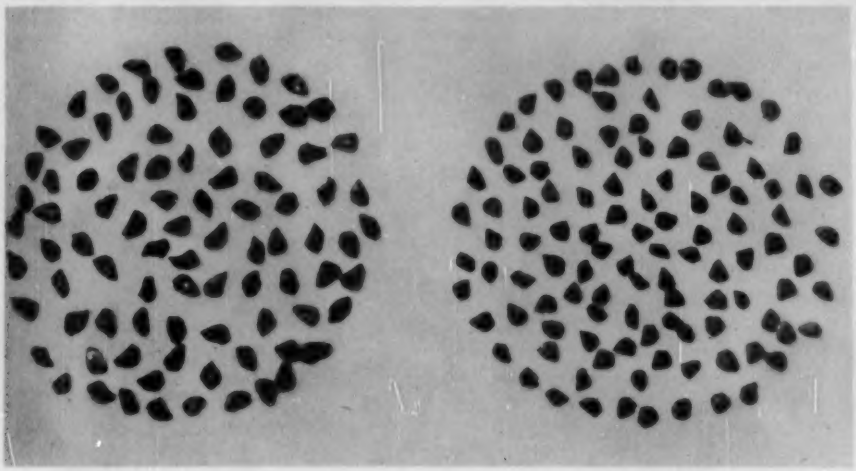

FIG. 4. Seeds of *Corchorus capsularis* (left) and *Corchorus olitorius* (right). ×2½.

Osmotic values are high when the plants are one to two months old, and they are maintained during active vegetative growth. There is a fall in osmotic value previous to flowering; although there is a rise subsequent to flowering, the value remains low compared with the value during active vegetative growth. The variation, therefore, is greatly influenced by the stage of growth and development of the plants and is not correlated with rainfall. The variation in *capsularis* is slightly different from that of *olitorius* (219).

Nitrogen and Mineral Nutrition. Agronomic trials have shown that nitrogen from inorganic or organic sources is a factor in increasing the yield of jute. Higher yields were obtained by applying inorganic sources than from organic sources (3D). There is a differential response to different combinations of N, P and K in *capsularis*. Ammonia is better than nitrate. Omission of K, P and Ca in nutrient solutions produced stunted growth, drying up of tips, chlorosis and bluish-green colour of leaves (221).

Variation in and Translocation of Photosynthates. Reducing sugars and sucroses are present in leaf, bark and wood of both normal and ringed jute plants at different periods of growth, but starch is present only in the leaf and is completely absent from mature bark and wood. These increase in the morning and decrease toward evening; maximum quantities are in the leaves, minimum in the wood. Sucrose is the sugar of translocation. Diurnal variation of total nitrogen in leaves and bark with maximum in the leaves at evening, has been noted. Total nitrogen decreases with increase in age of leaf and bark (32, 33).

Variation in Growth. Growth in height and basal diameter of the stem, and development of bark, wood and fibre show characteristic differences in the two species. Within the species varietal differences are also noted. High positive correlations in the variations of the different components during the different stages of growth obtain in both species. The ratio of fibre formation to wood formation varies with age from the vegetative to the flowering and pod stages. More fibre is produced in early than in later stages when more wood is formed. The calculated values of fibre formation on the total dry matter show more wood formation in *olitorius* than in *capsularis* (105, 106).

Salt Toleration. Watt (247) stated that only the coarser varieties of jute could be grown in the salt-impregnated soil of the Sunderbans in Bengal. Chaudhuri (31) reported that jute was successfully grown by him on high lands, about four feet above flood level, containing 0.20 to 0.25 percent of common salt. He observed that jute failed to grow on soils containing more salt.

Seeds of both *capsularis* and *olitorius* cannot tolerate a concentration higher than 1.0 percent of sodium chloride, and even at this strength there is a perceptible delay in germination. Seeds of *capsularis* are more tolerant than those of *olitorius* under similar conditions. *Capsularis* seeds, when previously soaked in 0.5 to 2.0 percent solution of sodium chloride for different periods, showed delayed germination with the increase of concentration up to 1.5 percent. Almost all the seeds treated with two percent solution failed to germinate (17). Experiments were conducted by artificially raising the sodium chloride concentration of soil by adding common salt. In soil containing 1.5 percent sodium chloride, the plants were stunted, the leaves pale yellow, showing less chlorophyll development, and very few flowers and pods were formed. When common salt was added to the soil at different ages (27 days, 74 days, 89 days) of the plant to make the concentration three to four percent, the effect was deleterious, and plants of all ages failed to survive (3C, 3E).

Germination of Seed Harvested at Different Stages. As early as 1927 there was a tendency amongst registered jute-seed growers, who were to supply the government seed with a guaranteed germination of 90 percent, to harvest the plants somewhat early in order to get a return from the fibre also. To determine the exact stage at which jute plants should be harvested to obtain seeds of the best quality, experiments were conducted at the Dacca Farm by B.D.A. in 1927 (2). Plants of both *capsularis* and *olitorius* were harvested when (*a*) stems

and pods were both green and pods were nearing maturity, (*b*) stems were green but pods ripe, and (*c*) stems and pods were both dead ripe.

Seeds were stored and their germination percentage was tested at periodical intervals. The results (2) indicate that in *capsularis* the plants can be harvested even when the stem and pod are not dead ripe. The best stage of harvest for obtaining *olitorius* seed of good quality is when the stem and pods are both dead ripe, but at this stage the pods tend to burst and to shed the seeds to some extent; as a result, there is loss of seed. It is, therefore, necessary that particular care be taken to collect seeds at the proper stage of harvest.

Experiments were conducted at J.A.-R.I. to determine the possibility of obtaining both fibre and seed of good quality from the same plant (3F). Plants were harvested when the pods were green, half mature and fully mature; the top portions were cut for seed collection after drying; and the stems were retted for fibre. To estimate the loss of fibre yield when tops were removed for seed, whole plants were also retted. By removal of the top portion for seed, the yield of fibre was not appreciably affected, the reduction being one-half to one maund per acre. The germination capacity of seeds collected at different stages showed that in *capsularis*, normal germination was from the second and third stages of harvest. In *olitorius*, germination percentage was highest in the third stage, although seeds of fairly good germination were obtained in the second stage of harvest also. The yield of seed was, however, highest in the last stage.

AGRONOMY

Soil

Jute can be grown on all types of soil varying in texture from clay to sandy loam. It thrives very well on soils of alluvial origin. It does not grow well on very sandy lands without the addition of large quantities of organic manures. Laterite and gravelly soils are not favourable. The "chur" or "khadar" lands, i.e., inundated areas near river banks, are very suitable for the crop. These lands are sandy loam and are usually renovated by deposits of silt left by annual floods. A good crop can be raised on nearly all types of land which are neither very sandy nor heavily clayey, provided the soil is deep enough and the rainfall is well distributed over the months of March, April and May.

In West Bengal and in East Bengal (East Pakistan) most of the jute is grown on alluvial tracts which are usually slightly acidic. Soil profiles are described in detail elsewhere (97) as well as physical structure and chemical composition.

The old alluvial soils in many jute-growing tracts are undergoing laterisation and are red. A portion of the western part of North Bihar is calcareous and the soil is alkaline with a pH of 10.55. The soil in other parts of Bihar is acidic, the pH being as low as 5.0. These soils are suitable for growing paddy, jute, sugarcane and potatoes, but not for "rabi" (cold weather) crops (150). The soil profiles, except those of the eastern parts of North Bihar, do not show distinct horizons. In the eastern regions of North Bihar there are distinct layers of yellow silt, fine sand and coarse sand, alternating with one another in different depths of soil layers.

In Assam the bulk of jute is grown in the Assam Valley where the soil is acidic and the acidity increases with rainfall and heaviness of soil. The soils of the northern bank of the river Brahmaputra are conspicuously less acidic than those of the southern bank. The soils of Surma Valley are more or less similar to those of Assam Valley (176).

The soils of Tripura and Manipur States are of reddish clay and good depth. The soil of Orissa ranges from

sandy to clayey and is slightly acidic. In Uttar Pradesh jute is grown in the Terai areas where the soils vary from slightly acidic to slightly alkaline.

Climate

Jute is grown during the rainy season, and thrives best with an annual rainfall of about 60 inches, of which ten inches fall in March, April and May. Damp heat is most favourable. In areas where jute is grown the maximum temperature does not usually exceed 100° F. or fall below 60° F. during the crop season, but in many parts of West Bengal, Orissa and U.P., the maximum temperature during the growing period may occasionally be as high as 110° F. or sometimes more. Humidity varies from 65 to 95 percent. It has not been possible to grow jute successfully during the cold season.

Sowing of seed starts by the middle of February and is continued until the middle of June in some areas. The monsoon in most of the jute areas except Assam sets in towards the middle of June, and the crop that is sown from mid-February to May has to depend entirely on subsoil moisture and pre-monsoon "nor'-wester" showers. In many areas, cultivators depend almost entirely on premonsoon showers for sowing.

In eastern and northern Bengal premonsoon rains start early and amount to more than 15 inches. In West Bengal they begin usually by the second week of April and amount to about nine inches. Pre-monsoon rains total three to eight inches in Bihar and about six inches in Orissa. In Assam the rains start much earlier. The total ranges from 50 to 70 inches in West Bengal, about 60 inches in Orissa, 45 to 70 inches in Bihar, 90 to 120 inches in Assam, and 70 to 90 inches in East Pakistan. The minimum rainfall required has not yet been determined. Jute has, however, been successfully grown in areas of Uttar Pradesh in India where the rainfall is between 35 and 40 inches.

Alternate periods of sunshine and rainfall are beneficial. Young plants are very sensitive to water-logging conditions which usually check their growth. When nearly fully grown, *capsularis* plants are tolerant of water which does not actually submerge them. It is, therefore, necessary to adjust the sowing time in such a way that the crop may attain a height of three to four feet before heavy monsoon starts.

Capsularis jute will thrive well in inundated lands if the floods do not come before the crop has reached a height of three to four feet; but in such cases the lower portion of the fibre tends to become very coarse by formation of adventitious roots.

Land Preparation

Preparatory tillage of land starts just after the first rain the latter part of February or beginning of March. As the roots of jute are more than a foot in length, deep ploughing is necessary to remove the stubbles of the previous year. Jute seeds are very small, and therefore the soil should be thoroughly pulverised and a seed bed with fine tilth obtained. In India and Pakistan the seed bed is prepared by ploughing and cross-ploughing five or six times. After each ploughing a log of wood or a ladder of bamboo, seven to eight feet long and weighed down by the cultivator standing on it, is drawn over the ploughed surface. This process of "laddering" levels the land, breaks up soil clods, loosens and collects the weeds, and compresses the soil slightly. Clay soils usually require more ploughing.

Manuring

Manuring is done differently in the various jute-growing areas. Cow dung, ashes and composted house sweepings are usually used. Cow dung is applied at

the rate of 50 to 100 maunds, i.e., two to four tons, per acre, and ploughed in during land preparation. In many areas where it is available, water hyacinth, either composted or in the form of ash, is applied. The ash of water hyacinth contains about 20 percent of potash and is highly suitable as a manure for jute. Both mustard and castor cakes are also used but the practice is not very widespread. Silt from tanks, ponds and ditches is utilized wherever available.

In the districts of Hooghly and 24 Parganas, West Bengal, wherever jute is grown in rotation with potato, the former is not manured, since the heavy doses of cow dung and oil cakes applied for potato are not fully utilised by it and the jute is benefited by the residue. In low lands which are silted annually by floods, manures are not usually applied. Compost was not much used in manuring jute fields previously. As a result of the vigorous propaganda of the agricultural departments of the various Indian States for making and using composts, application of them as manures for jute has increased.

Till recently artificial manures or inorganic fertilisers were rarely used for manuring jute. Inorganic fertilisers were not always readily available in the villages far from towns; besides, the cultivators could not afford to pay for fertilisers. In addition, there was a belief among the cultivators that use of inorganic fertilisers would deplete the soil. Dissemination of the results of research among the cultivators and the initiative taken by the Government for making the fertilisers more readily available in the remote villages, have lately spurred the use of artificial fertilisers, particularly of ammonium sulphate.

Nitrogenous manures and fertilisers have the highest influence on the vegetative growth of the plant (3, 31, 34, 37). Of the various inorganic nitrogenous fertilisers so far tried, ammonium sulphate has given the best result. By application of 20 to 40 lb. of inorganic nitrogen per acre, fibre yield increased up to 200 percent. Amongst organic sources of nitrogen tried so far, town compost has been the best. Less response was observed with sludge or farm yard manure. From experiments conducted at Burdwan Farm, Chaudhuri (31), however, concluded that farmyard manure (cowdung) is the best of all the organic manures, the next being castor cake. Town compost was not, however, included in these trials. Best results were obtained by application of town compost at the rate of 40 to 80 maunds per acre at the time of preparatory tillage, followed by 100 to 200 lb. of ammonium sulphate applied as top dressing when the crop was about a month old. Such mixtures provide 30 to 60 lb. of available nitrogen per acre (3C-F).

FIG. 5. Flowers of *Corchorus capsularis*. ×3.

Potash alone did not usually have any direct effect on the yield of fibre. Slight increases in yield by addition of 25 to 50 lb. of potash as muriate of potash were noticed when applied alone or in combination with lower levels of nitrogen; but these increases were, in many cases, not significant. Addition of potash has, however, been found to check diseases (2, 3E, 4).

No positive responses were obtained by application of phosphate so far as yield of fibre was concerned (3, 4, 33, 34), but such applications may prove useful in phosphate-deficient areas, as indicated by preliminary trials at J.A.-R.I. Recently Kundu and Mukerjee (137) reported that application of phosphate prevents lodging. It may therefore be tried in light soils.

Addition of calcium as lime is beneficial to normal growth in acidic soils. Increased fibre yields were obtained in some of the district trials by applying three to six maunds of lime per acre either alone or in combination with nitrogen. In non-acid soils, however, the role of calcium, like that of potash, is mainly in protecting the plants against disease (2, 3E, 70).

Jute does not appear to be an exhaustive crop. From analytical data of soil samples drawn before sowing and after removal of the crop, it has been found that soil is not depleted so far as total nitrogen is concerned. From preliminary experiments at J.A.R.I. (3E, 3F, 137, 153, 154), soil nitrogen exhausted during the growth of jute is replenished by normal leaf fall. The phosphate content of surface soils increases when jute is grown for a number of years.

Sowing

Seeds are sown broadcast, ten pounds per acre for *C. capsularis*, six pounds for *C. olitorius*. As the seeds are very small, they are often mixed with loose earth for the convenience of handling at the time of sowing. Sowing is carried out crosswise, that is, first from north to south and then from east to west, thus ensuring fairly even distribution of the seed. After sowing, the land is harrowed and then laddered, so that the seed is covered and comes in close contact with the moist soil, which helps germination. In order to ensure uniform germination, the seed should lie one inch to one and a half inches below the surface of the soil.

Vegetative growth as well as yield of fibre are greatly influenced by the time of sowing. In *capsularis* satisfactory yields have been obtained with sowings between March 16 and May 1. In *olitorius* sowings between April 15 and May 16 have given significantly higher yields than other sowings (220, 230, 231).

Yield of fibre in *capsularis* sown after May 16 and in *olitorius* after June 15 progressively decreases. Plants of both species sown in September and later show slow growth, and those sown in November, December and January have very poor growth (230, 231). Both species grown at J.A.R.I. attained a height of eight to twelve inches and developed very few capsules; but the capsules were fully developed and showed normal dimensions, and the number of seeds per capsule was also normal. Plants raised from such seeds in the normal jute season showed normal performance with regard to height and base diameter, but they flowered earlier (3D–E).

Weeding and Thinning and Sowing in Rows

Seeds with a germination percentage of about 80 produce about 1,000,000 potential plants per acre, but the final stand harvested usually ranges from 100,000 to 200,000. The seed-rate of jute, therefore, is very high. Although it is possible to raise a good crop with much lower seed-rates under favourable conditions, this high rate is considered necessary for the following reasons: (*a*) the germinating seedling is very delicate and often cannot singly break through the soil crust that may form when there is rain soon after sowing; therefore, it requires the help of other seedlings for emergence; (*b*) until the regular monsoon sets in sometime in June, the young crop is often subjected to long periods of drought, since the nor'wester showers, on which it depends, are irregular; therefore, in the event of mortality of seed-

lings during drought, an adequate population is ensured; (c) the thick stand in the initial stages helps to check the growth of weeds.

During the first two months of the crop, a large number of plants must be thinned out gradually. When the plants are three to nine inches tall, they are thinned by a hand rake (bida or anchra) drawn over the land. This operation may be repeated twice during the next fortnight. Weeding is important. After the initial thinning with a rake, the crop is weeded with a hand hoe (khurpi) two or three times, accompanied by thinning to about four inches. With more spacing the height and thickness of the plants increase; with too much spacing, however, the plants bring forth branches which are not desirable (2, 4).

Jute responds very effectively to the foregoing intercultural operations which should be carried out in time. If these are neglected, the crop will not grow properly, the outturn of fibre will be much less and the crop may even fail. For these operations 45 to 60 men are required per acre. This alone accounts for 40 to 50 percent of the total cost of fibre production. Weeding and thinning have to be carried out very expeditiously within short periods. During this period, the supply of labour is inadequate, and for this reason interculture is not often done satisfactorily.

Sowing jute in rows, however, and interculture by ordinary wheel-hoes worked by hand gives very satisfactory results (3C–F, 124, 197, 198). By this method seed-rates are reduced by about 50 percent, more uniformity in growth is ensured and the cost of weeding and thinning is cut down by about 60 percent. In line-sown crop the yield of fibre in *C. capsularis* is increased by 30 percent, and in *C. olitorius* by 16 percent over broadcast crops.

In trials from 1948 to 1951 at J.A.R.I., seeds were hand-dibbled in lines and interculture was given by wheel-hoes. By 1952, however, a continuous-sowing hand-pushed jute seed-drill to suit the growers with small holdings was designed. As sowing by this drill was continuous, the different spacings used within the line were adjusted at the time of thinning. Among those tried, a spacing of 12 inches between the lines and of two to three inches between plants in the lines gives comparatively higher yields, though the various spacings, 1″, 2″, 3″ and 4″ , between plants within the lines were not statistically different (3A–D).

Rotational Cropping

Annual crops cannot normally be produced economically year after year on the same land; for this reason crop rotation is usually practised. Jute, planted for fibre production, occupies the land only about four months, and it is possible to raise a different second or sometimes even a third crop the same year. Such a programme of double or triple cropping is possible in low- and midlands where rains start early or where irrigation facilities exist. In such areas *capsularis* jute is sown early, and after the harvest of jute, a crop of transplanted paddy often followed by a third crop of pulse can be raised. In high lands where sowings are late, the land is usually cropped with late varieties of jute, generally *olitorius*, which is followed by a crop of potato or pulse. Being a bast fibre crop which can be harvested at any stage without complete loss of yield, jute offers an advantage over grain crops which can be harvested only after maturity of grain. In a programme of cropping paddy lands with jute as an earlier crop, the transplantation of paddy, the time for which is fixed for each area, need not be delayed for the maturity of the jute crop (235, 236).

Experiments have been conducted at the farms of J.A.R.I. at Chinsurah and at Nilganj for double and triple cropping paddy lands with jute as an earlier crop. Economical yield of fibre from the first

crop (jute) is obtained when the crop is allowed to stand for a minimum period of 90 days before transplanting paddy. Harvests at later stages give better fibre yields and therefore higher profits. When early and late types of jute are harvested at the same time, the late variety tends to give higher fibre yields. For paddy, however, the earlier transplantation was advantageous, and application of manure to paddy crop had little or no effect if the transplantation was delayed beyond the optimum period (middle of August under West Bengal conditions and middle of July under East Bengal and Assam conditions). For a double cropping programme, therefore, the date of sowing and harvest of jute are to be so adjusted that transplanting of paddy is not delayed beyond this date. Depending on the time of harvest, the yield of *capsularis* jute is 15 to 20 maunds and that of paddy ranges from 19 to 23 maunds per acre. Where irrigation facilities are scarce, pulses like khesari (*Lathyrus sativus*) can be sown on a standing crop of paddy the latter part of October or the first part of November when the land is still moist, and a yield of six to 10 maunds of pulse can be obtained at no extra cost, except the cost of seed, sowing and harvesting. In areas where irrigation facilities are available, lentil (*Lens esculentus*), pea (*Pisum sativum*) or gram (*Cicer arientum*) can also be grown (135).

Harvesting

Jute plants may be cut at any time before they are fully ripe, but harvesting is not usually done before flowering. In flooded areas the crop may have to be harvested sometimes even before the appearance of flower buds for fear of complete destruction by early flood. Since the plants are immature at this stage, the yield of fibre is low.

The ideal stage of harvest is when the plants are in small pods. In most places, except in the flooded areas, jute is harvested at this stage, when both yield and quality are good. If harvested earlier, the yield is lower, and if harvested when the pods are fully mature, the yield of fibre is slightly higher, but the quality is reduced.

From experiments on stages of harvest conducted at Burdwan Farm in West Bengal for four years from 1905 to 1908 and at the Dacca Farm in East Bengal for seven years from 1932 to 1938, it was found that the longer the crop was allowed to grow, the heavier was the yield. The yield at flower stage is higher than that at bud stage, and the yield at pod stage is higher than that at flower stage (2, 246). Experiments at J.A.R.I. have confirmed these results (3A–B).

The plants are cut close to the ground with a sickle. In flooded areas, particularly in many parts of East Pakistan where the flood water comes very high, the workers have to dive under water to cut the plants. In one dive a trained worker can cut six to eight plants. In many low-lying areas where the crop is two to four feet in water at the time of harvest, plants are pulled out and the root portions are usually cut off before steeping.

In high lands the harvested plants are left in groups at different places of the farm for two to four days, when most of the leaves become dried. After this period the plants are tied into bundles six to nine inches in diameter. At the time of bundling, the plants are shaken, when most of the leaves fall on the ground. In many places the harvested plants are immediately made into bundles and are laid on the ground in long narrow lines, so that the leafy tops of one set of bundles cover the bare lower portions of the stems of another set. After two to four days the leaves fall and the bundles are taken for steeping in water. During the subsequent two to four days, the tissues shrink and cells

rupture. This facilitates the entry of microorganisms into stems when steeped. In low lands where jute plants may be standing in water, steeping is carried out immediately after harvest.

effected by the combined action of water and microorganisms.

The tied bundles of stems are taken to the nearest pool or ditch for retting and are laid flat in the water two or three

FIG. 6. Root of *Corchorus capsularis*. Tape is 3½ feet long.

FIG. 7. Root of *Corchorus olitorius*. Tape is 4½ feet long.

Retting

Retting is the process by which the fibres in the bark become separated from the woody parts through removal of pectins, gums and other mucilaginous substances between them. This is usually

feet in depth, arranged side by side so as to form a platform. The layer of bundles sinks partly from weight. If the water is deep enough it may be possible to have a second layer of bundles over the first and at right angles to it, and even a third layer. The top layer is

covered with weeds or other refuse and is submerged by weighting it down with logs of wood. Whenever these are not available, the cultivators use banana stems and/or clods of earth which are objectionable because they discolour the finished fibre to some extent.

Disintegration of tissues during retting starts from the cambium and extends to the ray cells, phloem and cortex, finally liberating the fibre bundles from the wood (174). Presence of periderm hampers retting and lowers the quality of fibre. Preliminary studies on the accompanying biochemical changes in the plant have been made (139).

By the time the top portions of stems are retted, the thick lower parts are still unretted, and if the lower portions are allowed to ret properly, the tops become over-retted. To ensure uniform retting of the whole plant, bundles of stems should be placed upright in about two feet of water for two to three days before they are completely steeped. The retting process is completed in eight to 30 days. The time required depends upon the maturity of the plants, temperature, and other conditions of the water. In the earlier part of the retting season, near the end of July, when the temperature of the water is about 85° F., the process may take only eight to ten days, but as the season advances and the water becomes cooler, a longer period is required, which may be three to five weeks after the end of September.

Considerable experience, care and close watching are necessary to determine when retting is complete and the fibres are ready for extraction, which must then be carried out as quickly as possible.

Retting can be successfully done by chemical treatment (3D–F, 29, 201), but it has not yet been tried on a large scale. The cost would be much higher than that of the ordinary process (162). Use of different substances for stimulating the growth of microorganisms responsible for retting has shown encouraging results (3D–F).

Extraction

Fibre is removed from the stalks of retted jute by hand. A labourer, who stands two to three feet deep in water, takes up, in his left hand, a handful (six to ten) of the retted stems and gently beats them at the base with a wooden or bamboo mallet. The fibres at the bottom are thereby loosened. He then breaks the woody core, one to two feet from the base. With slight jerks the pieces of broken stems from the base are taken out and thrown on dry ground. The loosened fibre is grasped by the right hand and the remaining portions of the retted stems are jerked backward and forward in the water, thereby separating the fibres from the sticks. Taking a bundle of fibre, the labourer lashes it on the surface of water and again pulls it towards himself by a few jerks, by which the adherent bits of periderm and wood are got rid of. Finally he spreads out the clean fibre on the surface of the water, and picks off any bits, if still adhering, by hand. Water is then wrung out of the fibres, and the latter are dried in the sun over a bamboo frame for two or three days, then tied into bundles for market. During drying, the fibre is bleached by the sun. A labourer can strip 20 seers (40 lb.) of dry fibre per day, working for six to seven hours. A highly skilled labourer can, however, strip up to 80 lb. of dry fibre during the same period.

In many districts of East Bengal (East Pakistan) and Assam (India) retted stems are stripped singly. The retted bundles are taken out of water and drained. The labourer, sitting on the edge of the tank, holds the root end of a small bundle in the left hand and separates the lower end of the fibre of each plant with the right, holding the stripped fibre between the fore and middle fingers of that hand. After the fibres

of all the stems in a bundle have been loosened at the bottom, the fibre is gently pulled apart from the stems.

In some areas this method is used with a slight variation. The labourer takes one or two (not more) stems and, by running the closed hand down the stem, removes all the adventitious roots and part of the periderm. He then loosens the fibre at the bottom, and, holding the stem in one hand, runs the fingers of the other hand along it to separate the fibre. When a sufficient quantity of fibre is collected, it is washed in clean water and dried. This kind of stripping is usually done by women and children. The process is slower, and only 20 to 30 pounds of fibre can be extracted in a working day, but the quality of fibre is considered to be better. In some parts of East Bengal a skilled woman can strip as much as 40 pounds of dry fibre in a day.

In some flooded areas of East Bengal and Assam, the plants are often steeped where they are cut. When retting is complete, they are carried in a boat or on a raft made of banana stems to the dry land for stripping. Some of the retted stems are stripped by a labourer sitting in the boat or on the banana-raft, but the major part of the operation is performed after reaching dry land.

Yield of Fibre

The yield of fibre depends upon a number of factors, among which are fertility of the soil, variety sown, care of the crop, stage of harvest, season and incidence of diseases and pests, and the fibre content of the plants. The last mentioned ranges between 4.5 and 7.5 percent of the green weight, with an average of about 5.5 percent.

There is a common saying among Bengali cultivators that the yield of a crop is at the rate of one maund (1 md. = 82.29 lb.) per bigha (one-third of an acre) per hat (one and a half feet) of the crop. This is a rough estimate for small crops and is equivalent to saying that the yield in maunds per acre is equal to twice the height in feet. Although this approximation is more or less true, higher yields may be obtained when the average height of the crop exceeds eight feet (73). On well cultivated and manured land, an outturn of 30 maunds of fibre or more may be expected. Normal average yield per acre is about 13 maunds in India and about 16 maunds in Pakistan. In India the yield is about 15 maunds per acre in Assam, 14.5 maunds in West Bengal, while in Bihar, Orissa and U.P. it is about ten maunds.

Seed Production

The best quality of fibre and seed cannot both be obtained from the same crop of jute because plants left standing until maturity of seed yield fibre of inferior grade. Furthermore, if a fibre crop is to be followed by a different kind of crop the same season, it must be harvested much before the seeds ripen. For these reasons, fibre and seed crops of jute are grown separately. The cultivator usually keeps a small portion of the crop at some corner of his field to produce seeds sufficient for his requirements. If he finds any surplus after meeting his own needs, he may sell it in the village markets. According to a marketing enquiry conducted by the Indian Central Jute Committee, the average area retained for seed is 4.1 percent of the total acreage under jute (93).

Only high lands or mid-lands are suitable for seed production. Low land areas are usually not used for seed production, as the plants are liable to damage by floods. Cultivators in certain areas of East Bengal (East Pakistan) and Assam, where the jute lands are usually inundated, get their supplies of seeds elsewhere.

Rainfall in October or November may damage the seed pods, thereby deteriorating the quality of seed. Certain dis-

tricts of Bihar and U.P., where there is no rainfall in October or November, are best suited for large scale production of seeds. Seeds with a germination percentage of 80 or more are usually considered good.

Early sown crops do not yield sufficient seed. With late sowings higher yield is usually obtained. The seed ripens usually by October or November, four to six weeks after the harvest of the fibre crop (71). The yield of seed of *capsularis* jute is four to five maunds, that of *olitorius* is two and one-half to three maunds, per acre. With proper care higher yields may be obtained. At the Chinsurah Farm of J.A.R.I., up to 11 maunds of seed for *capsularis* and six maunds for *olitorius* have been obtained.

Seeds immediately after harvest contain on an average 21 percent moisture. After two days of drying in the sun the moisture content falls to 17 percent; after three days it falls further to 9 percent; and to an average of 7 percent after four days. Jute seeds during development are liable to infection by the fungus *Macrophomina phaseoli*. Abundant moisture in the seeds helps the pathogen to remain viable in a mycelial stage or to pass to a sclerotial stage during storage (87).

Jute seeds are very delicate and soon lose viability if not properly stored. On account of the high moisture content of freshly harvested seeds, it is necessary that before storing, seeds be dried in the sun at least four days. After each day's sunning, seeds should be properly cooled and finally stored in dry earthen jars or seed bins (87). Cultivators usually store seeds in earthen pots fitted with lids sealed with clay to keep them air-tight. The pots are then put in a dark cool place or hung from the roof to avoid breakage and also to exclude dampness. It is common practice among cultivators to mix the seeds often with ordinary wood ash in order to protect them from insects. When produced in large quantities, the seeds must be kept on a platform in a reasonably dry room. Seeds, if well dried and properly stored, may retain their viability even after four years.

The performance of plants raised from one- to six-year-old seeds with regard to yield and quality of fibre is almost the same (2, 3D).

Cost of Cultivation

The cost of cultivation and production of jute fibre varies very widely from State to State, and even in different parts of the same State, depending on local practices, soil and climatic conditions, and the socio-economic condition of the jute growers. In certain parts of India, e.g., Orissa, the wages of labourers are lower than those in other jute-growing areas, and consequently the cost of production in such places is lower than in West Bengal and Assam. The average cost per maund over the different States ranges from Rs 15/- to Rs 26/-.

A detailed study of the operational cost of jute cultivation over a number of years has revealed that so long as the method of cultivation remains the same, there is very little variation in the relative proportions of operational cost. Nearly four-fifths of the total cost is accounted for by human labour, one-tenth by cattle labour, the rest by seed and manure in varying proportions. The operational stages required for cultivating this crop and previously discussed in this article, are irrigation (wherever done), ploughing, laddering, manuring, sowing, weeding, harvesting, steeping, stripping and drying. From the operation-wise distribution of human labour cost, weeding involves nearly one-third; ploughing (including laddering), harvesting and stripping each one-sixth of the total man-days required. The other operations (manuring, sowing, steeping, drying) together account for the remaining

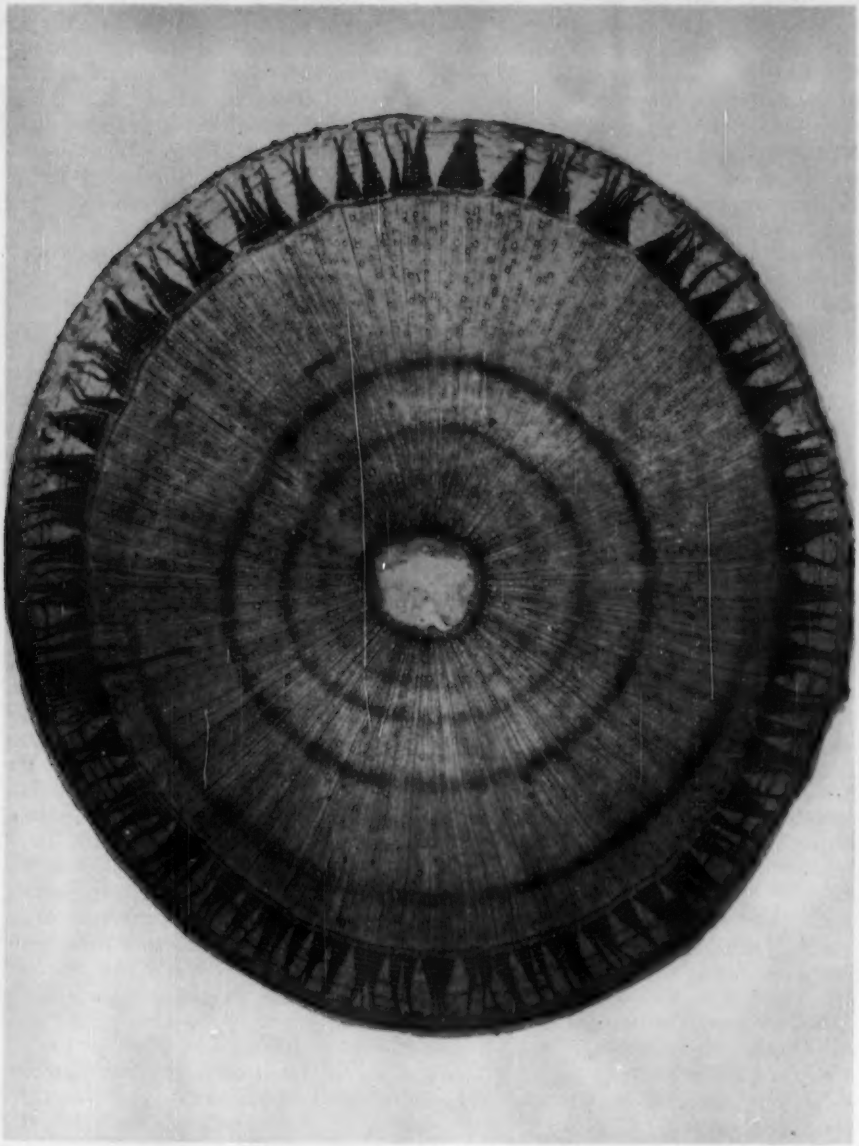

FIG. 8. Cross-section through stem of *Corchorus capsularis*. The fibre-producing areas are the dark peripheral wedges.

one-sixth. Nearly 75 man-days per acre are necessary for all operations combined, although this is subject to great variation from place to place. The seed used per acre is approximately ten pounds for *capsularis* jute and six pounds for *olitorius* jute, while the quantity of manure consumed by the growers is a highly variable factor, depending much on the soil constituents and its availability at low cost.

A comparative study of jute and paddy cultivation shows that the cost per maund for jute is nearly double that for paddy; this higher operational cost for the former is accounted for mostly by the increased cost involved in human labour.

The cost of cultivation and production of jute fibre is different for the two species. In broadcast jute, the cost of cultivation is generally higher than that in row-cropped jute. In line-sown crop, the space between the plants in the line is more uniform and the yield is usually increased. In trials conducted at J.A.R.I. during the five years from 1948 to 1952, increased yields by row-cropping were obtained in all the cases; even when the seeds were hand-dibbled in lines by labourers the cost of cultivation was appreciably reduced (3A–D). The increases in yield due to line sowing were higher in *capsularis* than *olitorius*.

DISEASES AND PESTS

Fungi

Fungi causing important diseases of jute crop, with conseqent loss in yield and quality, are *Macrophomina phaseoli* (Maubl.) Ashby, *Sclerotium rolfsii* Sacc. and *Diplodia corchori* Syd. Besides these a number of other fungi attack plants at various stages of growth, and cause minor damage (38, 184, 241).

In the report of B.D.A. for the year 1909–10, *Rhizoctonia* was first mentioned as a fungus causing root-rot of jute, potato, linseed and brinjal (*Solanum melongena*). In 1912, Shaw (232) stated that root-rot caused by *Rhizoctonia solani* Kuhn. is " almost the only fungal disease observed on jute ". Sawada (206) in 1916 reported stem-rot of jute from Formosa and stated that it was caused by *Macrophoma corchori* Sav. Shaw (234) in 1924 decided that the fungus reported by him previously as *R. solani* was *Macrophoma corchori*. He also found that the pycnidial form was restricted to jute. Ashby (5) in 1927 showed the sclerotial stage of the fungus causing root-rot of jute to be *Rhizoctonia bataticola* (Taub.) Butler, and, after comparing all the available cultures and carrying out inoculation tests, he found that the pycnidial stage responsible for the spread of the stem-rot disease was *Macrophomina phaseoli* (Maubl.) Ashby.

Macrophomina phaseoli attacks the jute plant at all stages of growth and causes the most serious and widely prevalent diseases (95). According to the parts of the plant attacked and the nature of attack, terms like " seedling-blight ", " stem-rot ", " collar-rot " and " root-rot " are used to denote the disease caused. When seedlings are attacked, necrotic lesions are formed on the hypocotyl, on the collar or on the cotyledonary leaves. Under wet conditions such seedlings damp-off, and the condition is known as " seedling blight ". Necrotic lesions occur mainly along the apex and margin of the leaf, ultimately covering the whole of it. Necrosis often continues to the petiole and from there enters the node where it starts stem-rot. At a later stage, pycnidia develop on the attacked leaves; pycnospores from such leaves are dispersed by wind and are responsible for secondary spread of the disease. Lesions may develop longitudinally or horizontally on the stem, girdling it, and the plant often dies as a result. In many cases fibres from the affected regions shred. In vigorously growing plants, the lesions are localised and cankers are formed. Attack at col-

lar regions is termed " collar-rot ", and plants suffering from collar-rot often die. The tap root is also affected directly by the fungus in the soil; the disease is then known as " root-rot ". Plants affected by root-rot wilt and gradually die. Capsules are also sometimes attacked, resulting in discoloration. The infected capsule may split, in which case the fungus enters and infects the seeds (1). Diseased seeds are lighter in colour; dormant mycelia of the fungus or sclerotia remain within the seed or within the seed-coat (243).

The pathogen is seed-borne as well as soil-borne. The over-wintering phase is mainly sclerotial. Sclerotia are found on almost all diseased parts, namely, stubble, stems, pods and seeds. Pycnidia are formed usually on leaves, sometimes on the stems. Pycnospores are the source of heavy secondary infection (1, 3, 234, 242).

Soft-rot is caused by *Sclerotium rolfsii* Curzi (= *Corticium rolfsii* Sacc.) which is mainly soil-borne (88). Usually it starts growth on decaying jute leaves on the ground in July and August. Infection begins in the stem at ground level. The stem turns brown and is often covered with white mycelia. At later stages, brown mustard-like sclerotia are formed on the affected portions, from where the fibre layers shred and as a result the plants lodge. In all cases of attack the plants are ultimately killed. The only practical remedial measure is to remove the old decaying leaves, from which infection starts. Attack through air-borne basidiospores is also known.

Black-band disease is caused by *Diplodia corchori* Syd. and is usually prevalent during the middle of July (3, 31, 233). Attacked plants wilt and are completely defoliated. Pycnidia develop all over the stem which appears black, due to development of sooty spore masses in abundance. It usually attacks naturally weak plants or plants weakened by other agencies.

FIG. 9. Fibre-cells of jute.

Recently it has been found that a species of *Colletotrichum* causes anthracnose in jute. *C. capsularis* is more susceptible than *C. olitorius*, but some varieties of the former are fairly resistant. The disease starts in the hot humid days of late July and is most widespread during late August. Initially, small brownish-black spots appear on the stem, which in course of time coalesce, forming cankerous tissues. The stem usually breaks when such tissues yield to the weight of the crown or strong wind (3, 101).

Minor diseases are mildew caused by *Oidium* sp. (241) and leaf spot caused by *Cercospora* sp. (38, 158). *Phyllostictus* sp. (3) and *Phomopsis* sp. (4) induce oval necrotic lesions on the stem but without seriously affecting the fibre.

Chlorosis

Finlow was the first to observe yellow and light-yellow patches on the leaf surface and applied the term " chlorosis "

to the variegated appearance. Investigations were started in 1917 and continued for a number of years. In 1918 it was reported that only two cultures were immune to chlorosis. In experimental inoculation of non-chlorotic plants with sap of chlorotic plants in 1925, chlorosis was not transmitted to the non-chlorotic plants. Hence it was concluded that chlorosis of jute is not due to virus. Chlorotic plants were found to have less surface roots. Non-chlorotic plants pollinated with pollen from chlorotic plants produced progenies showing great increase in the proportion of chlorotic plants. It was concluded that the mode of inheritance was not Mendelian (8). The causes leading to chlorosis were, however, not investigated fully (2, 31). In 1939, Finlow (73), while reviewing the work on jute, referred to chlorosis as a "morphological imperfection" and suggested that concentrated attention be given to the study of this phenomenon.

Work on this aspect has been started at J.A.R.I. It has been found that plants may be chlorotic from the very early stages or may become chlorotic later at any time during the vegetative period of the plant. In mild form the imperfection is not harmful, but in severe cases the leaves become crinkled and brittle, and growth is checked. *C. olitorius* is the less affected.

The problem appears to be complicated, and work on this phenomenon is being carried out in two directions to determine whether it is a virus disease transmitted through pollen or seed, or is a genetic phenomenon.

It was recently reported (86) that chlorosis may be caused by a virus. A number of grafts were made between chlorotic and non-chlorotic plants, and vice versa, using inarch and cleft methods of grafting. Chlorosis was transmitted in both directions, that is, chlorotic stock transmitted chlorosis to healthy scions, and chlorotic scions transmitted it to healthy stock. Transmission was slightly delayed in the latter, however.

True breeding chlorotic cultures have also been established, and crosses have been made between chlorotic and non-chlorotic plants in both directions. The crosses between non-chlorotic and chlorotic plants failed to germinate. The germination in crosses between chlorotic and non-chlorotic was, however, good, and all the F_1 progenies were chlorotic. Successful back-crosses of the F_1's with both chlorotic and non-chlorotic parents have been obtained (3F).

Nematodes

Corchorus olitorius has been mentioned as a host for the root-rot nematode, *Heterodera merioni* (Corusi) Goodey, in the list of hosts compiled by the Imperial Bureau of Agricultural Parasitology, 1931. Nematode attack in both cultivated species of jute was first described by Kundu (120). He observed that numerous root-galls form in infected plants. Comparatively less damage is done to the crop when the population of nematodes in the soil is low. In extreme cases the plants remain stunted and the development of leaves is poor; leaves may also become etiolated and all the plants may die before flowering. Brinjal is an important alternate host. Repeated cultivation of jute in the affected field increases the extent of attack.

Insects

During all stages of growth, beginning with that of the seedling, jute is liable to damage by various insect and mite pests (9, 10, 26, 48, 50, 60–62, 142, 143, 250). All parts of the plant body are subject to attack, and yield as well as quality are affected. Of the pests causing heavy damage, the following may be mentioned: *Anomis sabulifera* Guen. (jute

semilooper), *Diacrisia obliqua* Wlk. (hairy caterpillar), jute mites, *Apion corchori* Marsh. (jute apion), *Laphygma exigua* (indigo caterpillar) and the recently recorded *Nupserha bicolor* Thoms. ssp. *postbrunnea* Bruen. (ring pest).

Anomis sabulifera (jute semilooper) is widespread. The caterpillar is responsible for the damage done. It has a green body with yellow head and a semilooping mode of locomotion. It attacks the crop when the latter is about three feet high and ravages it for about two months. It feeds on the apical leaves and often damages the growing tip. As a result, growth in height is usually checked and a number of side branches are put forth. Fibre length is shortened with consequent loss in yield. DDT and BHC are effective for control (3, 31, 50, 73, 95, 143, 250).

Diacrisia obliqua (hairy caterpillar) also occurs abundantly. The full-grown caterpillar is very hairy and has an orange-coloured body with both ends black. The young caterpillar eats the softer leaf tissues, leaving only the upper epidermis and a skeleton, while the old ones devour the entire leaf. Though they usually cause damage to older leaves only, in severe attacks the plants may be entirely defoliated. As the young caterpillars are gregarious and remain grouped for about a week after hatching, the attack can be checked by plucking the leaves with the clusters of young caterpillars and destroying them with kerosinised water. DDT and BHC are effective (3, 31, 50, 73, 95, 143, 217, 250).

Jute mites are minute leaf-sucking creatures of two types, namely, white mites (*Hemitarsonemus latus*) and red mites (*Tetranychus bioculatus*). The white ones are more widespread and occur in the mid and high land areas, while the red are less common and are restricted to low-lying areas. Mites damage the crop by sucking the sap from the leaves which thus become discoloured and drop off prematurely. Growth is stunted and yield is affected. Two dustings of lime-sulphur in the ratio of 3:1, 24 hours apart, effectively control the pest (50, 95).

Apion corchori (jute apion) is also a very common pest widely distributed throughout the jute-growing areas. It causes damage to the crop at all stages of growth. The insects puncture the apical parts of the stems at the bases of petioles and lay their eggs singly in the holes. It is the grub of the insect, not the adult, which is responsible for the damage. The attacked plant can be recognised by its withered and drooping tops and leaves. At the point of attack, the stem is punctured, swollen and discoloured. As a result of the injury, mucilagenous substances which ooze out cement the cut ends of the fibre bundles with the adjoining tissue into a hard mass, and this resists separation of fibres during retting. As the insect is very small and completes its life history protected inside the stem, it is difficult to control and check it by insecticides. DDT and BHC are often used to prevent egg-laying (3, 31, 48, 95, 143).

Laphygma exigua (indigo caterpillar) is an important pest for seedling jute. Caterpillars of the pest cause damage to the young leaves. They are gregarious during the early part of their life and at this stage are more destructive to the seedling jute. BHC and DDT are effective for control (3, 95).

Nupserha bicolor ssp. *postbrunnea* is an important pest for *olitorius* jute, while all *capsularis* varieties appear to be completely immune. Egg-laying females are responsible for the damage done. They cut the stem about 16 cm. below the apex, and the cut portion soon dries up and dies. Plants 100 cm. to 200 cm. tall seem to suffer more than others. Yield is much decreased as a result of such attack (3, 61).

The Mexican Candelilla Plant and Its Wax[1]

About eight million pounds of this wax, obtained from wild plants in northern Mexico and adjacent parts of Texas, have been used annually in the United States in recent years—three million of them in the chewing-gum industry, the rest in the manufacture of coating and polishing preparations.

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Introduction

Plant waxes occur as epidermal secretions which form a superficial layer impervious to the passage of water. Such waxy coats are most frequent on those plants which must regularly endure prolonged periods of drought. The wax covering enables them to conserve internal moisture by cutting down excessive transpiration. That wax is not limited to xerophytes is shown by its occurrence on the stems of such mesophytes as sugarcane and species of bamboo.

Despite the development of synthetic waxes by industry, the need still exists for natural vegetable waxes. The United States regularly imports all its hard vegetable waxes and in a recent year (1951) brought in about 26,340,000 pounds, worth $21,082,000. Actually few plant waxes have been available in commercial quantity and it appears that some potential wild plant sources of wax have been overlooked. For example, a recent article in this journal[2] notes the occurrence of a carnauba-type wax, as yet unexploited, on the leaves of the abundant caranday palm (*Copernicia australis*) of Paraguay. It is a strange fact that wax from euphorbiaceous plants is obtained only from Mexico when the great concentration of desert euphorbias is in Africa; wax-producing species of potential value also ought to occur in southern Africa. In the United States new wax sources also are being found in domestic crops like sugarcane and rice, from which waxes may prove to be profitable by-products.

The better-known vegetable waxes of commerce are products of arid or semi-arid regions in this hemisphere. Most important is the wax obtained from the fan-like leaves of the carnauba palm (*Copernicia cerifera*) of eastern Brazil. Second in importance but less known generally is the wax of the candelilla

[1] This article is based in part on "Industrial Raw Materials of Plant Origin. III. A Survey of Candelilla and Candelilla Wax" by P. M. Daugherty, H. H. Sineath, and T. A. Wastler, 1953, Bulletin 16, Engineering Experiment Station of the Georgia Institute of Technology, to which publication the interested reader is referred for more information on the market potential of candelilla and for a complete bibliography. Unless credited otherwise, all photographs are by W. H. Hodge.

[2] Markley, Klare S. Caranday—Source of Palm Wax. Econ. Bot. 9: 39–52. 1955.

FIG. 1. A large flowering clump of candelilla (*Euphorbia antisyphilitica*) growing in the Big Bend National Park. (*Photo by Omer E. Sperry*).

(pronounced candayleéyah) plant, a stem-succulent, native primarily to the deserts of northern Mexico. Candelilla wax has a variety of industrial uses. These have increased in recent years and include water wax emulsions, polishes, insulation coatings, sizes, finishes, and bases for chewing-gum. The natural range of the candelilla plant extends slightly into the so-called "Big Bend" region of Texas, including parts of Presidio and Brewster Counties. Because of its occurrence in Texas there has been some interest in the possible cultivation of candelilla as a new crop for the arid Southwest.

The Plants Involved

Taxonomy. The plants supplying candelilla wax are all members of the family Euphorbiaceae. Several species of the genera *Euphorbia* and *Pedilanthus* are involved, but those of the latter genus apparently are of very minor importance as wax producers.

The botanist Zuccarini, in 1829, gave the name *Euphorbia antisyphilitica* to the Mexican plant now important as the chief source of candelilla wax. Zuccarini's description is brief but accurate as far as it goes. He made no mention of the wax of this plant but referred to the latex and its wide medicinal use in Mexico against venereal diseases. By the turn of the present century candelilla was known to be a potential source of hard wax, though its development as a commercial product did not gain recognized export status until about 1930. In 1909 Alcocer named the candelilla plant *Euphorbia cerifera* and gave a complete botanical description and illustration as well as a full account of the wax. Since Alcocer made no reference to Zuccarini's earlier name, it is possible that he was unaware of its prior publication. The plant described by Alcocer is not separable from that described by Zuccarini on the basis of their published diagnoses, and because of this the name *Euphorbia cerifera* Alcocer is regarded as synonymous with *Euphorbia antisyphilitica* Zuccarini.

Botanical description. The candelilla plant is a suffruticose perennial herb. The species apparently owes its Spanish name, meaning "little candle", to the form of its slender, pencil-thick stems. These are single or simply branched. The stems are numerous, thickly clustered, erect, and grow as much as three feet tall. Like desert cacti the candelilla belongs to that group of leafless stem-succulents whose tiny evanescent leaves are to be seen for only a very short time at the tips of the new growth. The paleness of the green color of the stems is caused by the scurfy covering of wax, the source of the commodity of commerce. The waxy coat is reported to be greater in the drier months of the winter. Also, plants growing in moist areas are said to produce less wax than plants occupying more arid sites. Candelilla is similar to other spurges in possessing a milky latex. The tiny inflorescences, appearing at the nodes along the upper portions of the stem, have the form characteristic of the genus *Euphorbia*. Flowering plants of candelilla have been observed in Texas from late April through June. In Mexico flowering is reported in July and August. As with many other desert plants, flowering cycles appear to coincide with the erratic rains.

Range. Candelilla is found throughout the Coahuilan desert formation, extending from the Mexican State of Hidalgo northwards to Coahuila and eastern Chihuahua, and including the adjacent Big Bend area of western Texas. The rainfall of this desert formation ranges from 4 to 22 inches per year. Although it occurs widely within its range, candelilla does not occupy all types of ecological sites in

FIG. 2. Stems of candelilla, showing the scurfy covering of natural wax, old flower clusters and a developing fruit (left). Scale shown in millimeters. (*U.S.D.A. photo*).

the desert. It apparently grows best on slopes where drainage is good, for it is seldom found in valley bottoms or on clay soils of the lowland desert plains.

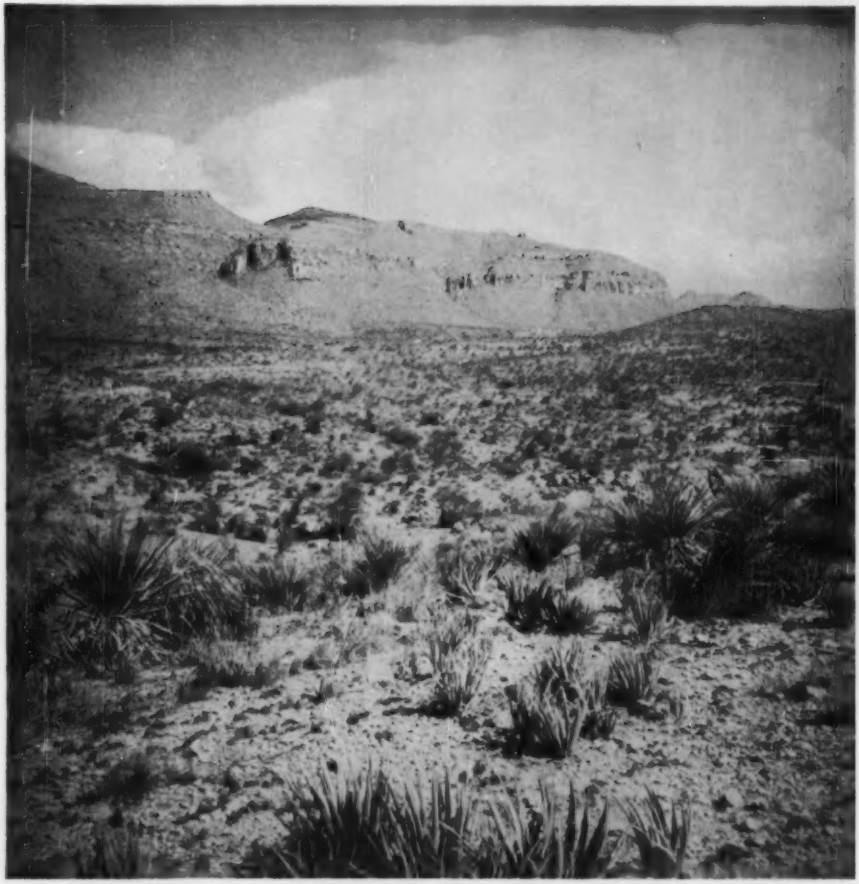

FIG. 3. Native habitat of candelilla near the Rio Grande in eastern Brewster County, Texas. Besides candelilla, other economically important species visible in the foreground are sotol (*Dasylirion wheeleri*), lechugilla (*Agave lechugilla*) and chinograss (*Bouteloua breviseta*).

In Brewster County, Texas, candelilla is abundant at elevations approximating 2500 feet above sea level. It associates there with such species as sotol (*Dasylirion wheeleri*), lechugilla (*Agave lechugilla*), chinograss (*Bouteloua breviseta*) and various desert microphylls. At this northern limit of its range, as elsewhere where candelilla occurs, frost is one of the controlling factors in its distribution. During severe freezes in the Big Bend National Park, candelilla plants are said to be killed back to the roots.

Harvesting. All candelilla wax is obtained from wild plants. Practically the

entire commercial production originates in the Mexican States of Coahuila, Nuevo Leon, Durango, Zacatecas, San Luis Potosí and Chihuahua. The cities of Chihuahua, Torreon and Saltillo serve as bases of operations for the main Mexican producing areas. The very small amount of wax produced in the United States originates from the Big Bend region of Texas and adjacent parts of Mexico. Although candelilla wax can be produced the year round, its exploitation is most extensive in the October to June dry season. Since this includes the winter months, labor is generally more readily available. Other agricultural activities are suspended at this time, and the wax content of the plants is claimed

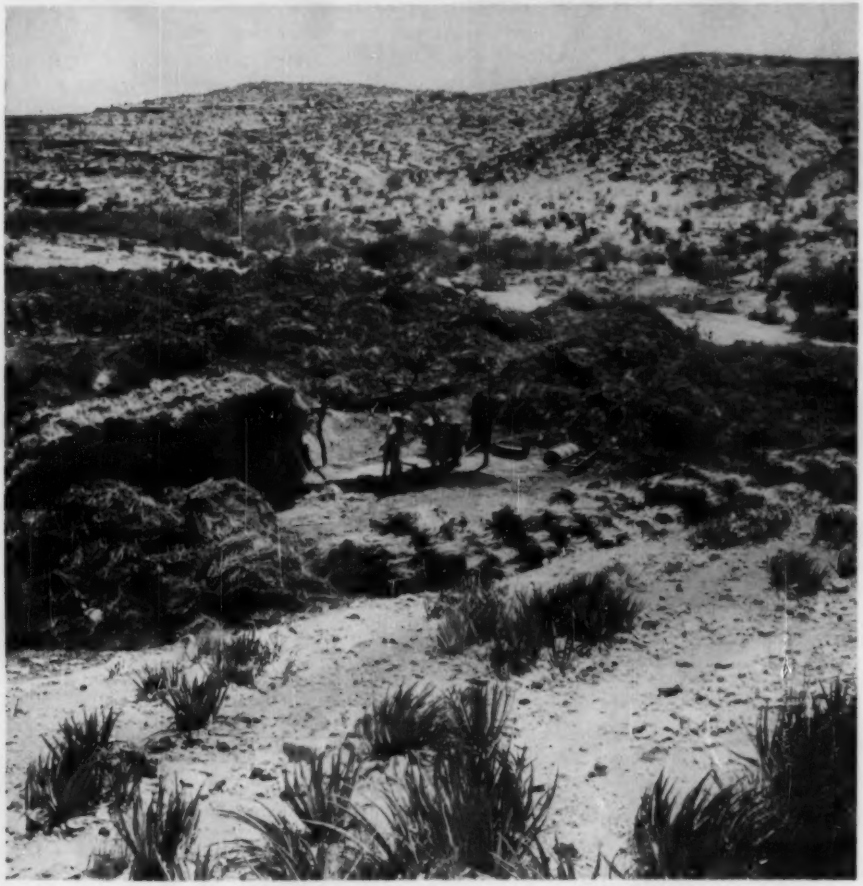

FIG. 4. Typical candelilla extraction camp. The crude shelter against sun (center) covers a sunken tank used for boiling the plants. Plants awaiting boiling are stacked in the tall pile at left and in the right foreground. The remaining piles are spent plants to be used as fuel.

to be higher than during the rainy season. Even when candelilla exploitation is carried out on a year-round basis it is sometimes the practice to harvest the plants during the height of wax production in the dry season and to stack them for later extraction during the rainier months.

The gathering of candelilla plants and the subsequent wax extraction constitute a primitive industry that is largely migratory in nature. Once an area with an abundant wild population of candelilla sufficient for exploitation is found by the wax harvesters, an extraction camp, or "fabrica", is set up. Since this production unit requires a regular supply of water, it is usually located near a stream, spring or some other dependable source of water. Candelilla gatherers range widely from the camp, using burros to carry collected plants back to the extraction camp, where they are stacked to await their turn for extraction. Where candelilla is abundant the gatherers may be able to collect up to ten tons per acre. The plants are usually pulled from the ground by hand, though they may be dug with a tool resembling a small spading fork. This method of harvesting often destroys the crown and a part of the root system but insures that the numerous stems are held together during subsequent handling. Exploitation of this type is highly destructive to the stands of wild candelilla, for few of the root systems left in the ground are able to reestablish new plants, particularly if harvesting is carried on during the dry season. One can readily see why a candelilla camp must migrate to another virgin area once one has been cleaned of its natural stands of plants.

Extraction of Wax. Little improvement has been made in the methods used for obtaining crude candelilla wax at the extraction camps. Because the producing areas are scattered and the yield of wax is low, plants in an effective area of operation are soon depleted and the extraction equipment must be disassembled and moved. There is a need, therefore, for the simplest equipment which can be readily carried by burro or mule over rough country. Basic equipment at an extraction camp includes a large rectangular tank, or "paila", usually buried nearly flush with the ground level. An opening is excavated beneath the tank to hold the fire required for boiling.

The extraction procedure calls for filling the tank with whole candelilla plants and covering them with water. The tank of material, or "paillada", is then heated to boiling by a direct fire fueled with spent candelilla plants that have been dried in the desert sun. These large fuel piles of spent plants are prominent features of candelilla extraction camps. About eight pounds of sulphuric acid are added for each 100 pounds of fresh candelilla plants. A metal grid is used to keep the plants submerged and to facilitate removal of the wax which floats to the surface as a light-colored foam. As it accumulates the waxy foam is carefully skimmed and transferred to another container to be held for further boiling. When most of the wax has been extracted, the plants are removed and stacked to dry as a source of future fuel. A fresh batch of candelilla plants is added to the tank and the whole operation is then repeated. From ten to 15 tankfuls, or "pailladas", is considered a good day's work.

At the end of each day the crude wax collected as foam from each "paillada" is again treated by boiling with sulphuric acid. This constitutes the first refining. The wax is then allowed to solidify, the water layer is drawn off from the bottom, and the wax cake removed from the drum or container. The center layer of the cake is cut out and shipped to refiners. The top and bottom portions, which contain a high percentage of foreign matter, are thrown

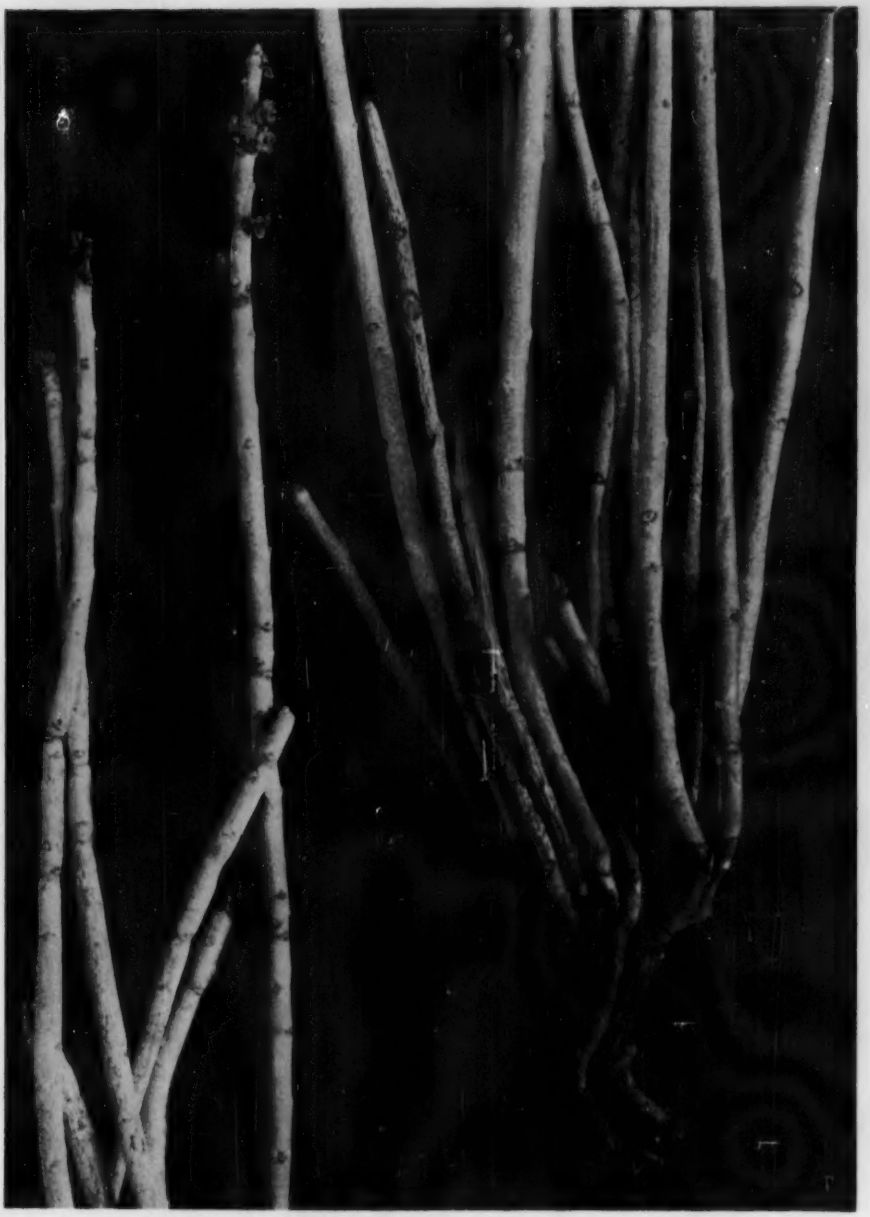

FIG. 5. A candelilla clump as harvested by hand. (*U.S.D.A. photo*).

back into the tank with the next charge of candelilla plants. The yield of wax is irregular, varying from 1.5% to 2.5%. The crude wax obtained, still containing about 10% impurities, including dirt, water and pieces of plant material, represents about 2% of the weight of the plant material used. For small-scale producers, this is the lowest limit of yield at which exploitation is profitable. Large-scale producers can operate profitably at a crude yield of about 1.75%. In general about 50 pounds of wax are obtained from a ton of candelilla plants.

For commercial use the crude wax prepared in the field at the camps must be further purified to remove the impurities and water which still remain. The possibility also exists that unethical workers may adulterate their wax with stones, dirt or clay. Normally the crude wax contains about 1% dirt and 7% to 8% water. The latter gives the wax a lighter buff hue which deepens to a rich

FIG. 6. Gatherers bringing in burro loads of candelilla plants to an extraction camp.

café au lait color upon final purification. The sole criterion for degree of purity is the color, judged by comparison with a standard block of wax. Physically refined candelilla wax is less adhesive and tacky than the crude field product because of partial removal of resins. Final purification of the wax is usually carried out in large vats by refiners, often at collection stations located in towns and cities in candelilla territory. In one local refinery observed by the senior author in Brewster County, Texas, the crude wax is placed in large vats of 5,000-pound capacity heated by butane gas, and simply melted down and cooked for several hours. The dirt settles out and the excess water is driven off as vapor. Once melted the refined wax is poured into moulds on a concrete floor to harden.

FIG. 7. Preparing to extract wax. The worker below stokes the fire with spent plants while a companion above readies the sunken tank with a load of fresh candelilla plants.

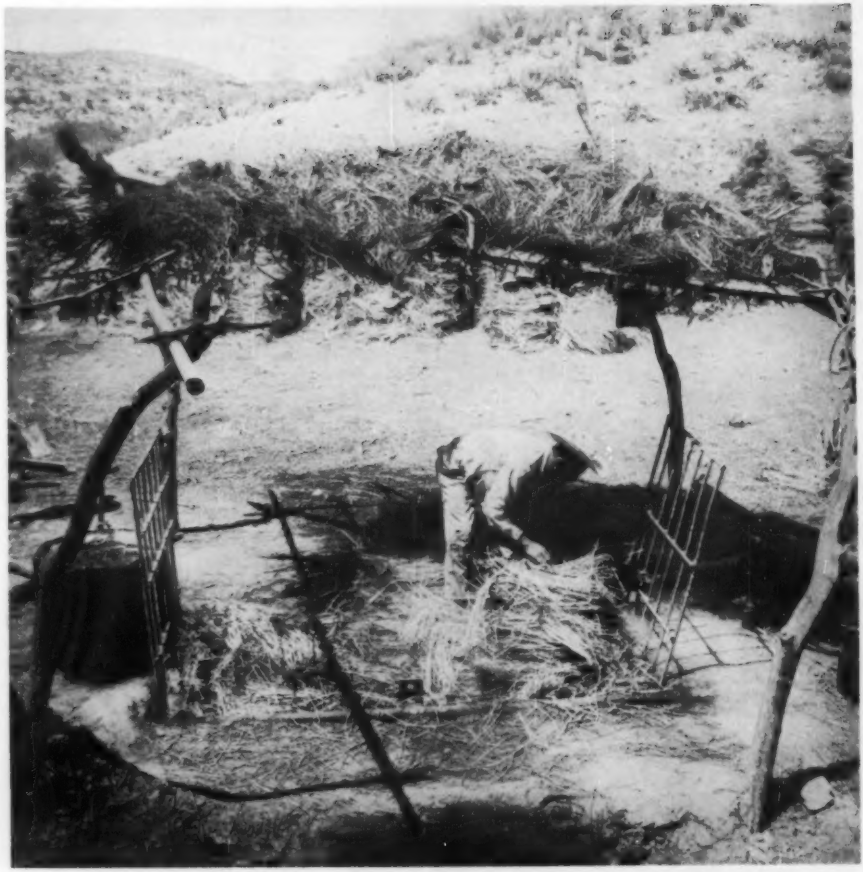

FIG. 8. The rectangular tank used to boil candelilla plants. The steel grids, at each end, fold down and are locked in position to keep the plants submerged during processing.

The wax is then broken up for ease in packing. It is marketed in bags, each holding about 170 pounds of wax.

At present the unit price of candelilla wax per pound received by the producer is approximately 70 cents. This represents the highest price paid since candelilla wax first came into the United States market in volume in 1936, when about 1,804,000 pounds were imported. In 1936 the unit price was 13 cents per pound. Annual production more than tripled during World War II; in 1946 the import was 10,880,000 pounds at a unit price of 28 cents per pound. For reasons discussed subsequently, production in the last few years has fallen greatly and now approximately equals that of the late thirties.

Candelilla Wax

Properties. The primitive methods employed to recover candelilla wax combined with the fact that in some areas

several wax-yielding species may be inadvertently gathered and mixed, result in a commercial wax that has varied chemical and physical characteristics. Another contribution to variability in wax composition is the fact that candelilla plants harvested during the winter season yield a wax proven to be higher melting and harder than that extracted from plants collected at other seasons. Also, plants of different ages yield waxes of different properties. The lack of consistent data on the properties of commercial candelilla wax is reflected in the fact that numerous standard reference tables either omit or say very little about this compound. The accompanying Table, giving various constants of *Euphorbia antisyphilitica* wax, was compiled from several sources. Each column represents a different literature reference and demonstrates the variability in existing records.

Candelilla wax is a yellowish-brown amorphous solid. It is soluble in organic solvents, such as acetone, benzene, carbon disulfide, carbon tetrachloride, chloroform, dekalin, hot petroleum ether, gasoline, and tetralin. The solubility of the wax in absolute alcohol is small; however, an alcohol-benzene (2–3) mixture is reportedly an excellent solvent. The fact that the resin components of candelilla wax are more soluble in alcohol than the wax itself makes alcohol a valuable solvent for purification.

Uses. Candelilla wax is used for numerous purposes. By Mexican country folk it is employed, after mixing with paraffin, for candles, which are said to "burn with a bright light and agreeable odor". As an industrial compound it is used as a substitute or dilutant for beeswax and carnauba wax. In addition to its service as a replacement or extender for carnauba, it is employed in certain

CONSTANTS OF CANDELILLA WAX

Melting Point, °C.	67–68	77.4	74–80, 77.4	77.2, 75.8–77.4
Setting Point, °C.	64.5	...	...	63.8–67.7
Saponification Number [a]	64.9, 84.1 [b]	104.11	104–108 105–106	105.7
Iodine Number	36.8, 33.6 [b]	5.23	5.23, 5–6	5.9
Acid Value	12.4 17.4 [b]	...	...	0.2
Density at 15° C.	0.9825	0.9473	0.9473, 0.9587	0.9807–0.9920 0.8550 (100°)
Refractive Index at 71° C.	1.4555	...	...	...
Acidity	...	0.03	0.03, 0.32	...
Fatty Acids (%)	6.57	...	...	...
Nonsaponifiables (%)	91.17, 84.2 [b]	...	...	...
Ash Content (%)	0.34	...	...	...
Hardness Value (Shore Durometer)	...	...	...	$100^{85°}$

[a] The ester of sitoserol ($C_{29}H_{49}OH$) and dihydroxymyricinoleic acid ($C_{30}H_{60}O_4$) constitutes about 20 percent of the ester portion of the wax. Also present are esters of the normal acids and alcohols—C_{28}, C_{30}, C_{32}, and C_{34}. Some free resin acids are present as well as amounts of the above acids.

[b] These are data on refined wax.

carnauba formulations as an additive to impart the property of so-called "tack" to the material. It serves as a hardener for soft waxes. Candelilla wax has been used as an ingredient in many specific compositions; chewing-gum compositions; cosmetic preparations; crayons; electrical insulating compositions; emulsion polishes; explosives; floor, shoe, and furniture polishes; insect-proofing mate-

FIG. 9. Wax extraction at a candelilla camp. One worker (background) pushes the floating wax layer to his companion who dips it out with a simple metal colander. The crude wax will receive another boiling before being allowed to harden in the sectioned drum in foreground.

industrial items, including acid-proofing agents for metal etching; adhesives and cements; automobile polishes; candles; carbon paper; lithographic, printing, stamping, and writing inks; celluloid rials; leather dressings; linoleum; lubricant bases; metal-protecting and moulding compositions (dentistry, precision castings, etc.); ointments; paint remover; paper sizing; phonograph rec-

ords; rubber compositions; sealing waxes; varnishes; water-proofing agents (fabrics, shipping containers, etc.); plastics (as plasticizer, filler, or base); and for moulding purposes (figurines, anatomical specimens, and the like).

FIG. 10. Removing the frothy floating wax from the boiling mass in the tank.

Apparently the major portion of the candelilla wax imported into the United States has been used in the manufacture of coating and polishing preparations, especially in paste-type materials. Estimates are that between four and five million pounds of the wax have been used annually for this purpose. In addition, the chewing-gum industry has consumed as much as three million pounds annually in recent years.

For use in some types of polishes, candelilla has been found to have several disadvantages. The wax contains a rather high resin content which imparts a tackiness to the products and causes shut-downs in production by fouling the reaction vessels. However, this property

has been used advantageously to impart nonslip properties to floor wax preparations. There has been a trend toward emulsion-type wax preparations, and candelilla wax is not exceptionally satisfactory in these. In liquid and so-called self-polishing preparations candelilla wax has a tendency to form objectionable gels.

FIG. 11. Spent candelilla plants being removed following wax extraction.

In addition to the sulphuric acid treatment, several methods have been suggested for refining candelilla wax in an attempt to decrease the resin content and to obtain a harder product. Some claim that candelilla wax of a lower resin content can replace carnauba in many applications. Selective solvent extraction of the resins has been demonstrated, as has the destruction of the resin components by means of oxidation with peroxides, permanganate and chromic acid. The treatment of candelilla wax with

organic acids at elevated temperatures to produce a harder, higher-melting (75° C.) product has been patented.

Although a wax, free of the bitterness of the present grades of candelilla, would be appreciated, the major objection that chewing-gum manufacturers have to candelilla wax is the current high price. Resistance to this price is being shown by the fact that one segment of this industry has already reduced its candelilla consumption by about two-thirds, while another segment has accelerated its search for suitable replacements for use in its products.

Candelilla wax, although known to commerce since about 1912, did not achieve much prominence until about 1936. Several factors contributed to the increase in imports of this material; among these were the promotional efforts of a Mexican producers' organization, and the increased demand for waxes brought on by World War II. The

FIG. 12. Chunks of crude candelilla wax as prepared at an extraction camp.

United States domestic production of candelilla has been a relatively small percentage of the import volume (estimated at about 10%) and has been sporadic; the Texas production increases the fact that most of the candelilla plants in the State grow within the boundaries of the Big Bend National Park and so are not available to the wax producers.

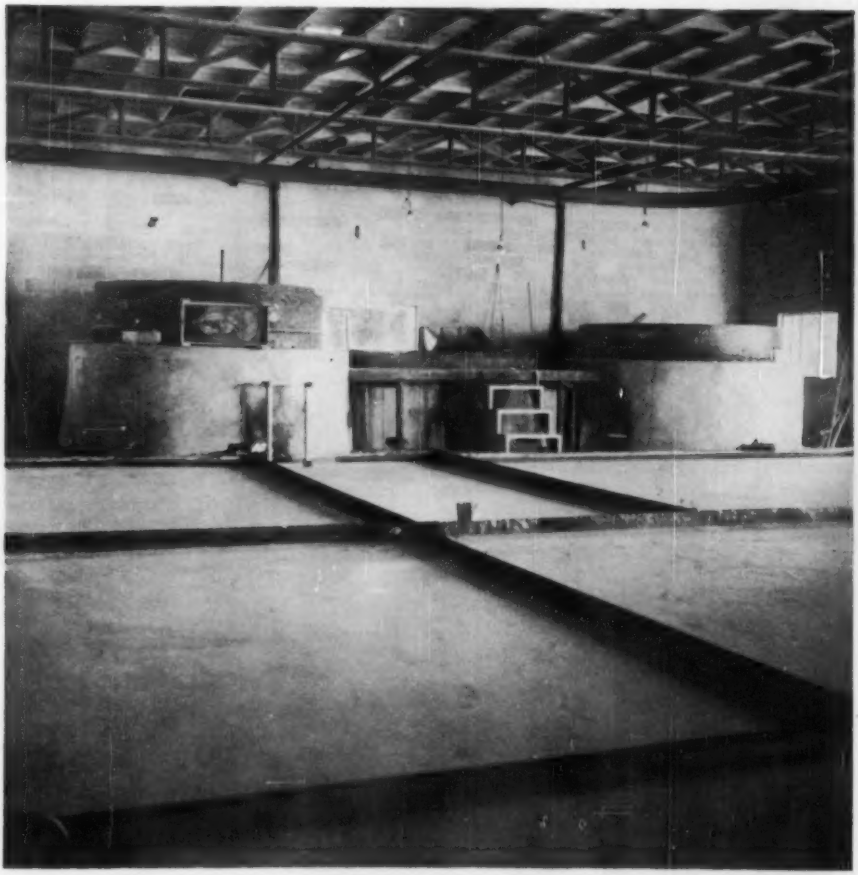

FIG. 13. Interior of a candelilla wax refinery. Crude wax received from extraction camps is refined in the large vats. The resulting product is then poured into the forms on the cement floor to harden while dirt is left as sediment at the vat bottom.

when the price is high (as in recent years, because of the Mexican embargo on candelilla export) but is practically nil when the price becomes "normal". Production in Texas is limited also by

In 1936 a group of candelilla producers, the Union de Credito de Productores de la Cera de Candelilla, was organized in Mexico for the purposes of collectively marketing the wax and im-

proving the conditions of the extractors. This organization controlled about 80% of the wax produced, and the resultant artificial prices stimulated excessive production. As a result the Mexican government intervened with corrective legislation in 1937. A federal export tax, equivalent to five cents (US) per pound, was placed on candelilla wax, and a subsidy equivalent to the tax was granted to the producing organizations. This arrangement was subsequently made more flexible to conform with actual market conditions. Thus, if the market value of the wax declines, the price is lowered by decreasing the tax. More recently the control of production and the sale of candelilla wax have been in the hands of another Mexican organization with similar functions.

FIG. 14. Candelilla wax being melted down in a vat during the refining process.

During 1947–1948 the production of candelilla wax was decreed prohibited by the Mexican authorities. Subsequently the decree was reinstated, the

prohibition against wax production extending to 1954. A severe penalty was provided for violations. This step was taken to halt the destructive exploitation of candelilla plants in the States of Chihuahua, Coahuila, Zacatecas, Nuevo Leon, Durango and San Luis Potosí, where, it is claimed, the species has been in danger of extinction. As would be expected, exportation of candelilla has shown a decreasing trend. One result of the decree has been considerable smuggling of candelilla wax from Mexico into the United States. In addition to smuggling of the wax there has been an increase in collection of plants on Mexican territory adjacent to the frontier and in the subsequent processing of the wax in extraction camps located just over the border in Texas. Mexican border patrols reportedly reduce the smuggling of wax considerably, but even so it is apparent that considerable quantities are brought into the United States.

FIG. 15. Dirt-filled wax obtained from the bottom of the vat after refining.

Candelilla as a Possible New Crop

Actually there is little danger of candelilla becoming extinct through excessive exploitation, for the plants grow on extensive areas of the Mexican desert country, too distant from population centers for profitable exploitation, as well as in the region where intensive harvesting has been carried on. Since the extraction of wax in the field requires quantities of water, candelilla also continues to thrive unexploited in areas that are accessible but where water wells do not exist or where transport of water is not practical. Nevertheless, intensive harvesting of candelilla plants in some centers has so depleted the available supply that there have been proposals to bring this species into cultivation. Before this can be done, much information, including that obtained by study of possible agronomic and cultural practices and comparative studies of the wax production of wild and cultivated plants, is needed.

FIG. 16. Weighing and bagging refined candelilla wax.

Apparently there are no records of attempts to cultivate candelilla commercially in Mexico, where the most suitable areas for its culture exist. Individual plants have been grown experimentally in the United States (Arizona and Texas) and elsewhere in semi-arid parts of tropical America. Reports available concerning these test plantings indicate that plants of *Euphorbia antisyphilitica* survive under culture but may produce much less wax than in the wild. Lower wax content may be associated with better moisture conditions under cultivation.

Under natural conditions candelilla reproduces by means of seed, but establishment of plantings of a perennial species of this type from selected clones by vegetative propagation presumably would be more efficient. Apparently the few experimental plantings made have been established with transplants from the wild. Although no published reports of studies on vegetative propagation of candelilla are available, there appear to be no major problems involved. Plants collected in Texas near the Big Bend National Park in late April 1954 were easily rooted at the United States Plant Introduction Garden, Glenn Dale, Maryland. Propagation was by cuttings or divisions in open beds of moist (not wet) sand without any growth regulator treatment. Roots formed readily if the cuttings were taken at the nodes, especially at those where new growth had already started.

Cultivation of candelilla is of special interest in relation to the use of range or unproductive submarginal land. A big problem is the actual establishment of candelilla under such conditions. Candelilla culture on irrigated soils also has its problems. Even if the wax production of cultivated plants does not decrease under irrigation, it is doubtful that candelilla could be grown as economically as other already established crops which might compete for space on the limited irrigable lands available. In the United States especially, where high labor costs prevail, it would be impossible without mechanization to compete with the Mexican wax product, whose price is already excessive in the opinion of industrial users. However, in addition to mechanization, the two principle factors which could affect this situation are increased yields and improved methods of recovery of the wax. Attainment of all these conditions would require effective experimental programs.

In the absence of such developments it would seem that commercial cultivation of candelilla is not an attractive prospect, at least not in the United States. As long as candelilla wax can be collected from the wild with cheap labor and as long as it can compete favorably with other natural or synthetic waxes, it will probably prosper as a minor industrial commodity. But if United States industry requires stable sources of hard vegetable wax, then it perhaps should look to less speculative and more dependable types, such as are currently being developed as by-products from sugarcane bagasse and the bran of rice.

The Culture of False Hellebore

Veratrum plants and seeds have winter dormancy which is relieved by cold. The germination behavior, storage life of seeds, requirements for nursery culture and possibilities of vegetative propagation are described in this article—also the habits of several species in the wild.

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Considering the extent to which several species of *Veratrum* are collected and used commercially, there is surprisingly little information in the literature concerning where, how or whether they could be grown as a cultivated crop.

Roots of the white false Hellebore (*V. album*), supplied mostly from Europe, have long been employed as an insecticide, though this use has diminished with the introduction of better chemical insecticides. The American or green false hellebore (*V. viride* (Ait)) has long been recognized as a drug plant.

Veratrum viride contains a complex of numerous alkaloids and glucosides, some of which have useful hypotensive properties plus others that are highly toxic. Due to the varying composition of this complex, the plant was not widely used in the medical profession. However, extensive research on the pharmacology of the individual components by the Riker Laboratories and earlier workers led to the introduction in 1950 of "Veraloid", a uniform mixture of the more hypotensive alkaloids. This work is well documented in the literature which is not cited here because it is outside the scope of this paper.

The taxonomic literature is replete with descriptions of the above-ground portions of *Veratrum* species and general descriptions of their habitats. However, little has been reported on the ecological factors responsible for their distribution, their feral reproduction, ontogeny or the morphological characteristics which would dictate methods of propagation suitable for culture. Agnes Arber's (1) book on the morphology of monocotyledons pictures the underground portions of *V. viride*. Youngken (6) studied the anatomy of *V. viride* and *V. Eschscholtzii* A. Gray and described distinguishing features in the roots.

The present investigations were confined to *V. viride*, *V. Eschscholtzii*, *V. fimbriatum* A. Gray and *V. Californicum* Durand. *V. viride* inhabits moist locations in the eastern United States where winters are severe. It is a pasture weed in some areas around Quebec, Canada, and in the New England States, and extends southward in the Appalachian mountains into North Carolina and Tennessee. There are anomalies in its distribution, however, which cannot be explained on the basis of climate, soils or moisture supply. Its alkaloid content is correlated positively with latitude.

V. Eschscholtzii, a species very closely related to *V. viride* and considered by some taxonomists to be a western ecotype of *V. viride*, is found in the Hudsonian Zone from the Bering Sea and

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coastal ranges of Alaska through British Columbia into the higher elevations of Washington and on Mt. Hood, Oregon, thence eastward into Idaho and Montana. It is confined to moist but well-drained sites within a rather narrow altitudinal belt from the timberline to slightly lower. Some of the author's observations covering the typical and some exceptional sites are quoted in Dr. Youngken's paper.

V. fimbriatum is confined to a narrow strip of coastal California from Ft. Bragg southward to Ft. Ross, a distance of only about 60 miles and one to three miles wide. It extends from sea level to a few hundred feet elevation. While its vegetative tops resemble those of the other species, its showy fragrant flowers and large succulent and wingless seeds as well as its adaptation to a special climate seem to indicate evolutionary changes not shared by any of the other species. The climate of its limited habitat involves moderate and very uniform temperatures. Mean daily maxima during June through November are within the range 61° to 65° F., and during December through February 51° to 59° F. Mean daily minima June through November are within the range 47° to 50° F., and during January and February 36.4° to 40.3° F. Light freezing in winter or day temperatures higher than 70° F., in summer are infrequent. The species' adaptation to the mild climate and long growing season have important implications with respect to possibilities of introducing it in to cultivation.

V. Californicum is well described in the literature. While the distribution is characteristically in moist locations at altitudes providing six months or more of snow cover, a number of strains were found at places near sea level where winters are mild. This variation was of little interest in the present investigations because the species lacks hypotensive alkaloids.

Sexual Propagation

Bailey's (2) comment that *Veratrum* is readily propagated by seeds or division is an oversimplification. Personal correspondence with people who have tried to grow it in quantity from seed indicates that the attempts have been partial to complete failures. Multiplication of the crowns is so slow that propagation by division is quite impractical.

Dormancy. The seeds and rootstocks of *Veratrum* have pronounced winter dormancy, requiring prolonged cold before resuming growth in spring. The seeds have embryo dormancy similar to that of many species native to cold climates. Relief from dormancy by "after-ripening" is accomplished by holding the rootstocks or seeds in moist aerated media at temperatures a few degrees above freezing. The optimum temperature and period vary by species and are somewhat correlated with the species' native habitats.

Youngken (6) reports obtaining only 8% germination during 11 months after planting untreated seeds of *V. viride*, and no germination of untreated *V. album* seeds within 15 months. *V. viride* seeds held for two months at a temperature range of 32° to 35° F. gave 28% germination within a year. By comparison with the results reported below, his treatment seems to have been far from the optimum.

In testing seeds of *V. viride* and *V. Eschscholtzii* from the 1949, 1950, 1951 and 1952 crops, their dormancy appears to be so alike that conclusions as to effects of treatments are probably equally applicable to both species. This in spite of greatly differing germination percentages due to the differing proportions of unfilled and insect-damaged seeds in the *V. viride* seedlots used.

Stratification at temperatures slightly above freezing provided partial relief of

dormancy the second and third months, but on removing the seeds to growing temperatures, germination was slow and to low percentages. After four to four and one-half months' stratification at 35° to 40° F., the seeds germinated promptly in the laboratory. In many tests, half of the total germination was attained during the first five to seven days and was complete at three weeks.

Germination percentages of the various seedlots of *V. viride* ranged from 22% to 65%, while those of *V. Eschscholtzii* ranged from 40% to 85%. The non-germinating seeds of properly after-ripened *V. Eschscholtzii* were those unfilled, damaged by insects or attacked by fungi during the after-ripening and germination periods. But in some collections of *V. viride* seed, substantial numbers remained plump and apparently sound for months after the run of germination was finished.

The stratification temperature range of 35° to 40° F. was more effective than 40° F. and slightly higher for relieving the dormancy of *V. viride* and *V. Eschscholtzii* seeds. When after-ripening was completed, the seeds sprouted at the lower range.

Dormancy of *V. Californicum* seeds was similar to that of *V. viride* and *V. Eschscholtzii* but was relieved by somewhat shorter periods of low temperature. Three months at 35° to 40° F. was apparently adequate for complete relief of dormancy. 70% germination occurred in two weeks; 74% at four weeks after moving the seeds to 70° F. temperature.

A comparison was made of the dormancy of two strains of *V. Californicum* —one from populations growing at elevations of about 3,000 feet in the Bitter Root Mountains north of Greer, Idaho; the other near sea level in the vicinity of Portland, Oregon. After 80 days stratification in moist perlite at 35° F., the seeds from the "high altitude" strain had broken dormancy and about 80% had germinated at that temperature. Within a week after moving the seeds to room temperature, additional germination brought the total to 98%. None of the "low altitude" seeds had sprouted at 35° F., and only 25% of them sprouted during the ensuing month at room temperature. But when the non-germinated seeds were returned to temperatures of 40 to 44° F., they broke dormancy and germinated within a week after the second transfer to room temperature. Total germination of this lot was 93%. Thus it appeared that the strain which had become adapted to the region of mild winters had acquired seed dormancy, responding to higher temperatures than those favorable to after-ripening (and actual sprouting) of the high altitude strain.

The seeds of *V. fimbriatum* are radically different from those of the species previously discussed. Not only are they different as to their dormancy but also in size, form and storage characteristics. They are succulent (containing about 80% water) and are killed by drying. The required period of moist storage at low temperature varied by seedlot, but usually two to two and a half months at 40° to 45° F. was adequate for complete relief of dormancy. Subfreezing temperatures were not injurious but were less effective for relieving dormancy. Also temperature 35° F. was less effective than the 40° to 45° F. range for this species. Acid peat was better stratifying media than the alkaline vermiculite or perlite, molds being prevalent in the latter two media.

The dormancy of *V. fimbriatum* also differs from that of *V. viride* and *V. Eschscholtzii* in that germination of non-after-ripened seeds is slow but not permanently inhibited. In one trial of non-after-ripened seeds, 60% germination occurred during four months at room temperature. This percentage was not greatly different from the totals ob-

tained in three weeks by after-ripened seeds.

Most of the trials of after-ripening of the several species were made at the temperature range 35° to 40° F., but sub-freezing temperatures also were tried. With *V. viride* constant sub-freezing temperature was entirely ineffective, and when temperatures alternated one week frozen and three weeks above freezing, the seeds failed to germinate promptly. However, seeds of *V. Eschscholtzii* transferred from 40° F. to sub-freezing and back every two weeks germinated about the same as from constant 40° F. stratification. No after-ripening occurred among seeds held in dry sand at subfreezing or at temperatures slightly above freezing.

Effects of Light on Germination. After ripened seeds of *V. viride* and of *V. Eschscholtzii* were sown in replicate in Petri dishes, four replications of 100 seeds of each being held in darkness and four in weak light at the same room temperature. The light intensity varied during the day, approaching one foot-candle at mid-day. The percentage means of germination at 16 days were:

	Light	Dark	Least sig. diff. @ 5%
V. viride	67.7%	57.5%	6.95%
V. Eschscholtzii ..	91.0%	81.0%	6.90%

The wings and outer seed covering are waxy, but apparently the failure of germination among dormant seeds is not due to impermeability. The seed wings do contain water-soluble germination inhibitor(s) which greatly retard germination of some species' seeds and prevent germination of others. However, the substances are not present in sufficient concentration to affect germination after stratification.

None of the following treatments was effective for obtaining germination of the dormant seeds: leaching, hot water, sulphuric acid, sodium hypochlorite, surface active agents, thiourea, dewaxing with acetone or hexane, nutrients or combinations of constant and alternating temperature.

In all of the species mentioned, saprophytic molds were common in the stratification media, but they seemed to live principally on empty or injured seeds. Fungicidal treatments such as Arasan, Dithane Z-78 and Parzate were not wholly effective; and 8-hydroxyquinoline benzoate in solution 1:1200 applied for 20 hours prior to stratification killed seeds of *V. Eschscholtzii*.

Storage Life. *V. viride* is subject to intermittent seed-bearing habits. A year of heavy crop is usually followed by five or more years of very scant bearing. Consequently the possibility of storing surplus seed is important to a production program.

There were rumors that *V. viride* is in the category of plants whose seeds must be sown immediately upon ripening; this did not prove to be true. Collections in the vicinity of Quebec in the fall of 1950 and 1951 were kept dry at room temperature for periods up to four months, then stratified at low temperatures for another four to four and a half months before sowing in Petri dishes. While some differences in germination percentages occurred, they were not related to the periods of storage.

Seed of the 1950 crop was stored, sealed and unsealed, at room temperature and at approximately 40° F. for testing at the end of one and two years. Moisture content of the seed at the beginning of storage test was 7.9%. Unfortunately the stratification treatments immediately preceding the periodic sowings were not standardized, though they were uniform for all lots represented in each test. The germination percentages attained at three weeks in the germinator were as follows:

Two months dry storage plus 4½ months in moist sand and peat, at temperature range 35–40° F. Total germination = 30%.

Twelve months dry storage plus 4 months in moist vermiculite at approximately 40° F. The obviously empty or insect-damaged seeds discarded from the test samples.

	Sealed stg.	Unsealed
Room temperature storage	0%	0%
40° F. storage	17%	12%

Twenty-four months dry storage plus 4 months in moist perlite at 35° F., then germinated in light.

	Sealed stg.	Unsealed
40° F. temperature storage	46%	2½%

In the above tests many of the non-germinating seeds from the cold dry storage lots remained plump and apparently sound well beyond the germination test period (storage-induced persistent dormancy?).

Thus it appeared that *V. viride* lost all viability during the first year of storage at room temperature, whether sealed or not; but if held sealed at 40° F. it may be kept for at least two years without loss of viability. When held unsealed at 40° F., it declined in viability by the end of one year, and only a small percentage of the seeds were germinable at the end of two years.

The higher percentage germination attained after two years (sealed at 40° F.) than at the beginning of the experiment probably was due to more effective stratification technique and to light used in the last germination test.

Storage of *V. fimbriatum* Seed. Storage of *V. fimbriatum* seeds is limited by the fact that they are succulent and that drying kills them. Attempts were made to hold these seeds in a moist but quiescent state by the following methods:

	Storage temperatures (a)	(b)	(c)
1. Submerged in water	25–30°	35–40°	70° F.
2. Moist, in CO_2 atmosphere	"	"	"
3. Moist, in nitrogen gas	"	"	"
4. In moist vermiculite (controls)	"	"	"
5. Damp seed sealed with air	"	"	"

At the end of two months when afterripening should have been nearly finished in the control 4-b, part of the series were germinated on blotters in Petri dishes at two temperatures (in darkness)—at room temperature of 70° F. and outdoors where night temperatures ranged from 35° to 40° and those of days from 55° to 62° F.

Germinations outdoors were nearly as rapid and to significantly higher percentages than at the 70° constant temperature. The seeds from lots 2-b, 3-b and 5-a were dead. Control 4-b germinated 60% at constant 70° F., and 77% outdoors, the final counts being made at 14 days. Lot 4-a germinated 39% at 70° and 62% outdoors—the germination of this lot starting about a week later than in lot 4-b.

At the end of ten months of differential storage, all of the seeds were dead. The inert gases preserved them from decay but, as noted above, greatly hastened their death.

The test indicated no way of storing *V. fimbriatum* seeds for use the following year.

Emergence and Early Seedling Growth. Numerous greenhouse and nursery sowings made under a wide variety of conditions showed that *Veratrum* seeds are extremely susceptible to the depth and kind of covering material. The linear primary leaf emerges doubled over in the shape of an inverted U, and slight matting or crusting of the cover medium prevents the distal portion of the leaf from emerging to assume an upright position. These die at the top of the loop and soon die back.

In greenhouse cultures, clean sand cover 1/16" deep permitted best emergence; and shallow cover with vermiculite or shredded spaghnum was nearly as good. In outdoor sowings of *V. Eschscholtzii*, failed stands were common in spite of unusual precautions. The most successful nursery sowing of this species was in the Wind River Valley of Wash-

ington. There the nurseryman sowed freshly collected seeds thickly on the surface of prepared beds and applied a thin covering of clean sand. Heavy snow followed shortly and laid at depths of four to ten feet during the winter. Emergence occurred just as the snow was melting, seedlings being up at one end of the beds when drifts of snow still covered the remainder. While the resulting stand was dense, it represented only about 10% of the seeds sown. Sowings of *V. Eschscholtzii* elsewhere resulted in poor to failed stands.

The large seeds of *V. fimbriatum* have more emergence vigor than those of *V. viride* or *V. Eschscholtzii* but are sensitive to cover material. In trials of sand, peat, vermiculite, perlite and shredded redwood bark in comparison with soil cover, surviving stands differed greatly. Cover materials which remained sufficiently loose to permit good emergence often gave stands representing half to three-fourths of the seeds.

Seedlings of this species as well as of *V. Eschscholtzii* were sensitive to sunlight, and, unless shaded, they turned yellow and the tops died back early in the season. The cost of providing special covering material and shade was partly offset by reduction in weeding costs. The peat was fairly effective in controlling germination and growth of weeds; and *V. fimbriatum* thrived in shade dense enough to repress weed growth appreciably.

The primary leaf attains full size quickly, but no other leaves appear during the first growing season. Development of roots and of a small bulb continues during the summer if light and temperatures are favorable to the top.

Nursery stand densities of 100 to 150 seedlings per square foot apparently were not limiting to growth. Sizes attained the first and second years by *V. fimbriatum* and *V. Eschscholtzii*, respectively, differed enormously. The very slow growth of *V. Eschscholtzii* seedlings is illustrated by the fact that 3,000 two-year-old seedlings plus their packing material were shipped in a one-pound tobacco can. Digging and transplanting them was exceedingly tedious.

In some instances, root diseases caused serious losses of *V. fimbriatum* nursery seedlings.

Vegetative Propagation

Veratrum is a monocot of the family Liliaceae, so its possibilities for vegetative propagation are distinctly limited. Monocotyledonous plants lack a continuous meristem as a sheathing cambium, and usually lack the ability to form callus tissue from which new roots might be expected to grow.

Crown Division. The general arrangement of the underground parts of *Veratrum* is that of an upright rhizome thickly set with whorls of fleshy roots and surmounted by a massive bulb-like crown bud. The bud consists of concentric fleshy scales which are basal remnants of the previous season's leaves. In the center of its base is incipient development of the second year's crown bud which is destined to form a shoot during the third season.

Meristematic activities are confined to an axial growing point at the junction of the rhizome and crown bud, where are initiated the new crown bud and root primordia in numbers characteristic of each species. Growth of new cortex and xylem moves the developing new roots in an expanding circle, and during the following growing season they emerge from the cortex to add another whorl of roots at the top of the root system. In some crowns of *V. viride* sectioned in August, the root primordia were in two concentric circles suggesting periodic initiation.

Numerous crown buds are initiated, but apparently the first one to develop exercises dominance, preventing develop-

ment of the remainder. Thus so long as the plant remains vegetative the crown remains single. However, upon the advent of flowering the flower stalk occupies the central position on the rhizome, and one or several of the otherwise suppressed buds develop to form independent crowns and eventually make a forked rhizome.

If the apical dominance of the primary bud could be suppressed, it should be possible to have numerous new crowns forming annually and a practical mode of propagation by division of the clumps. Substances presumably having anti-auxin activity, such as triiodobenzoic acid and ethylene chlorohydrin as well as traumatic acid and phytohormones, were used to treat dormant rootstocks of *V. fimbriatum* and to spray the tops repeatedly during the growing season. The treatments did not stimulate multiple crown formation, but this may have been due to lack of knowledge of the proper dosage and proper time of application. Dr. Went (5) experimented with an electrically heated needle pushed up through the rhizome to kill the new crown bud. In one instance where the injury was placed just right and not too extensive, numerous new buds formed. Later a device was used to drive a "comb" of blunt needles horizontally into the crown at a level likely to destroy the new apical bud. Mr. Chabot (4) reported that in some plants sprayed the previous growing season with colchicine, numerous new crown buds formed in the vicinity of the growing point. Thus there is experimental evidence that *Veratrum* plants are inherently capable of prolific annual increase by multiple crown formation.

However, the natural habit is for the crown to remain single from the seedling stage until the first year of blooming. This span is not definitely known but is probably seven to ten years. Thereafter they bloom only in occasional years, and flowering may or may not be accomplished by doubling or tripling of the crown. Frequency of blooming varies greatly by species and by habitat. Areas in the Sierras densely populated with literally millions of plants of *V. Californicum* were cruised without seeing a single bloom. In other seasons, scattered plants were found where 5% or more of the plants were in flower. Mature plants of *V. fimbriatum* bloom more regularly on the average than do those of *V. viride* or *V. Eschscholtzii*, but in some locations blooming is rare, and rhizomes showing ten years quota of root whorls had not bloomed during that period.

The rhizomes accumulate a new layer of tissue at the top with its accompanying whorl of roots each year, and the oldest lower portions disintegrate and slough off. Leaf scars leave an annual ring, and blooming stalks leave a distinctive scar as well as a diversion of the rhizome axis. Thus the age and blooming history of the surviving portion of the rootstock can be read rather clearly. There is no way of telling, however, how long the sequence of top increment and bottom discard has gone on. Judging from the indicated frequency of crown doubling, some of the clumps of *V. Eschscholtzii* examined in Alaska must have been more than a century old.

Severed Crown Buds. Attempts to increase the number of plants by splitting the crown and rhizome vertically into halves or quarters were unsuccessful. The mutilation and transplanting shock caused malformation and limited growth of the leafy tops which emerged; and only that division which happened to contain the growing point with preformed crown bud developed into a new crown.

Extensive trials were made of entire crown buds severed horizontally to in-

clude some of the top of the rhizome. This method, if successful, would have some practical aspects. Where native plants are harvested for commercial use of the roots and rhizomes, one could well afford to sacrifice part of the tonnage by removing and planting back the crown buds.

The author's trials were made with the crown buds from dormant plants of the species *V. viride*, *V. Eschscholtzii* and *V. fimbriatum* during three years. A preliminary trial was run, starting with dormant plants of *V. viride* collected in the mountains of North Carolina. The entire rootstocks were held in moist material at 35° to 38° F. from late October 1949 till February 20, 1950, to relieve dormancy. Then the crown buds were severed to include about one-quarter inch of the top of the rhizome and planted in a greenhouse, some in pasteurized medium fine sand and some in a potting mixture of loam, sand and composted manure. The upper half of the bud was removed from part of each lot, the idea being to restrict the amount of leafy tops which would be produced. Trial of indole butyric acid and of "Rootone" also was included.

The tops emerged in four days and were well expanded eight days after planting. Roots were slow to appear, but the tops survived with good color and turgor during the ensuing three months when the plants were taken up for examination. About half of the total number had made roots, ranging from one to 15 per plant and of sizes from pips barely visible to some four inches long, well clothed with lateral rootlets. Rooting was more prevalent in sand than in the potting mixture; and the hormone treatments appeared to increase rooting, though the limited supply of plant material prevented enough replication to be sure of this. There was no callusing at the cut surfaces of the rhizome nor of the root stubs which it carried. In many cases it simply rotted away without affecting the actively developing area above it.

The next trial a year later involved 78 treatments, each with four replications of five plants. It included several species and strains, severing the buds before or after the dormancy-breaking cold storage period, phytohormones and fungicides alone and in combination, several planting media in the greenhouse and some outdoor plantings.

Emergence occurred in the greenhouse plantings two days after planting, and the leaves of *V. viride* were expanded within a week. The tops retained good color and appearance for several more weeks. Deterioration of the tops was first apparent as browning and die-back at the leaf tips and occurred earlier among the Quebec Canada strain of *V. viride* than in the North Carolina strain. *V. Eschscholtzii* from Alaska made only limited and abnormal growth of tops, both from the crown buds and from the entire plant controls. An explanation of this is given in a later discussion of a peculiar inhibition of growth of this species when transplanted.

The surviving plants were harvested about six months after planting. On the whole, rooting was less frequent than in the previous year's trial, and obviously was affected adversely by the greenhouse temperatures. The Quebec strain seemed more sensitive to the greenhouse temperatures than was the North Carolina strain. Only two out of 740 of the Quebec strain rooted in the greenhouse, whereas 27 out of 160 (17%) of them rooted in an outdoor plot in shade where cooler temperatures prevailed. An additional 20% of them were still alive in the outdoor plot, though not yet rooted. Seventeen percent of the plants from the North Carolina strain of *V. viride* rooted in the greenhouse. Their tops were somewhat

smaller than the tops produced by entire rootstocks and the new crown buds were smaller, but there was no difference in the root systems of the two classes of plants. The old rhizomes and roots of the whole rootstock controls had rotted. The very low percentage survival destroyed the significance of the various other treatments involved.

Outdoor trials of crown bud propagation of *V. viride* were made in the vicinity of Quebec by Mr. Chabot (4) and Dr. Camp (3). The unpublished reports received by the author were rather incomplete, but apparently the results were not very favorable.

***V. fimbriatum* Crown Bud Propagation.** The concurrent trial of *V. fimbriatum* crown buds was made by planting the severed crown buds from freshly dug plants, their bases immersed overnight in water or in indole butyric acid solutions of various concentrations up to 100 mg./l., then planted in a prepared plot in their native habitat, 100 buds per treatment.

At the end of the ensuing growing season, part of the plants were dug up for examination and replanted. The percentages rooted ranged from 40% to 90% and directly correlated with the concentration of IBA used, 90% of those treated 100 mg./l. being rooted. Whereas crown buds three-quarter inch to one and one-half inches in diameter were planted, those produced were only one-quarter inch to one-half inch diameter.

The following year the question was investigated further, using concentrations of IBA 0, 100 and 200 mg./l., and planting 20 buds of each treatment at seven locations. Two of the locations were in sun and shade, respectively, at the native habitat about 60 miles south of Ft. Bragg, California, and the other plots were in the vicinity of Humboldt Bay which is considerably north of the native range but with very similar climate. These plots differed as to exposure and soil type. Each of the crown buds was measured to determine later whether rooting and survival was correlated with size.

V. fimbriatum differs from the other species in that the crown buds push above the ground surface in late autumn, rest briefly in midwinter, then grow furiously in late February or early March. The crown bud plantings made October 16th to 19th were inspected November 15th. At that time the numbers of buds which had emerged were definitely related to the IBA treatments. The percentage means were: untreated 10%, IBA 100 mg./l. 35% and IBA 200 mg./l. 58% and consistently in this order at all plots. However, the stimulation of early top growth was not followed by any significant effect on the percentages of plants emerging the following spring or on growth the following summer. In fact the 200 mg./l. treatment reduced the percentage of survival.

In the first spring after planting the severed buds, the tops grew about as quickly as and to the size of those from whole rootstocks; and the tops survived surprisingly long into the summer, supplied only with stored food reserves and water absorbed from the cut bases. Also the embryonic bud made considerable growth concurrently with top growth. But development of roots from the initials known to be present was very slow and many failed entirely. Where external roots did develop, they came so late that top activity was nearly finished for the season, and the new crown was so small and weak that a majority of them failed to come up the second spring. Thus the second year's survival became the criterion of real establishment.

Second year survival was in all instances of much lower percentages than from the transplanting of whole root-

stocks, and was correlated with the species' preference for shade, cool temperatures and protection from wind. In the first trial, where 90% of the plants showed some rooting at the end of the first growing season (in sun), only a few appeared the second spring. In the series of seven plots having various soils and exposures, the second year survival ranged from 0% to 60%. At the plots within the native habitat, survival in shade was 27% and in sun 0%. At Arcata, north of Humboldt Bay, a shady site had 50% survival and a nearby sunny (and windy) site had 1½%. At the less favorable sites many of the whole rootstocks survived but with poor growth, yellowish-green foliage and short season of top growth. Transplanting trials of whole rootstocks at inland locations where summer temperatures were higher than in the coastal zone were unsuccessful, though coastal locations as far south as Moss Landing in Monterey County permitted good growth of plants kept in shade and protected from wind.

There was one promising hint of a solution to the crown bud propagation of *V. fimbriatum*. In addition to the mid-October series of crown bud plantings described above, a mid-September planting was made at the sunny and windy site north of Arcata. In the third growing season these had 80% survival. Possibly the factor responsible for the inhibition of new root growth is something that develops with the ripening off and development of dormancy at a critical period in the fall.

Inhibition of root growth has been noted in more marked degree in whole rootstocks of *V. Eschscholtzii* transplanted in autumn. Dr. Went (5) held dormant *V. Eschscholtzii* rootstocks at low temperatures for periods up to a year without ever bringing them to a condition permitting normal growth. In the author's trials involving transplanting *V. Eschscholtzii* short distances in its native sites in Washington as well as the moving of Alaskan plants to various presumably suitable sites, the tops continued to grow for two years from food reserves stored in the original transplant, but with little or no root growth.

The root initials which had developed the summer before transplanting grew further only to the extent of showing as a ring of "pips" at the top of the rhizome. The crown which had been about two inches in diameter when transplanted, finally consisted of two crown buds one-half inch in diameter. Similar effects appeared among plants of *V. Eschscholtzii* on Mt. Adams, Washington, when moved only a few feet. They survived for two years but made no new roots. However, several exceptions were found. Some of the plants moved from Alaska to a site in northern Washington in the fall made new roots two or three inches long by the following May. Also one plant transplanted in northern Washington while in bloom thrived the following year, though it was not examined for root growth. Dr. Went surmised that root growth of *V. Eschscholtzii* may depend on hormone-like substances supplied by the root tips which are lost in transplanting. Such an hypothesis would be compatible with the easy re-establishment of *V. viride* plants which have a profuse network of lateral roots clothing the portions ordinarily moved.

Bulbels. Occasionally flowering plants of *V. fimbriatum* were found to bear axillary buds or bulbels. Their occurrence was rather rare, but when a plant of this habit was found the bulbels were usually present on several stalks of the clump. They were more slender than crown buds but of similar structure, some of them being as large as a man's thumb. Since they were enclosed by the sheathing leaf bases, they were difficult

to find until the stalks died in the fall, when the still green live buds protruded from the rotting leaves.

Attempts to use them as propagating material were mostly unsuccessful. One of them formed a more globose bulb having several roots but no leaves during the first year, and became a small entire plant the second year. Mr. Chabot (4) reported finding similar bulbels on flower stalks of *V. viride* near Quebec, Canada. These were on plants which had been sprayed with colchicine earlier in the season.

Fertility Responses. *V. viride* plants were grown as pot cultures in the greenhouse, with nitrogen, phosphorus and potash added singly and in combination. Two soils were used, one a naturally fertile sandy loam and the other a loamy fine sand of low cropping potential. The plants were indifferent to added phosphorus or potash, but nitrogen significantly reduced their growth. Suppression of growth by added nitrogen was more pronounced in the naturally fertile soil than in the poorer soil.

Conclusions

Veratrum of the several species studied could be grown from seed on a commercial basis. However, the cultural requirements are very exacting and the seedlings must be tended in a nursery under suitable conditions for a number of years before transplanting to fields. The larger-seeded *V. fimbriatum* is easier to grow than *V. viride* or *V. Eschscholtzii* but is exacting in climatic requirements.

Field plantings must be confined to locations where the species' climatic and moisture requirements are met. In most locations shade is necessary, either by artificial means or by other plants. This would increase production costs. The crop cycle from seed to harvest of roots large enough for suitable tonnage was not determined but is estimated to be at least ten years.

Propagation of *Veratrum* by replanting crown buds taken from harvested rootstocks would shorten the crop cycle. Further research is needed to learn the techniques for successful use of this method. The practice would involve sacrificing 25% to 35% of the harvest tonnage.

So long as native *Veratrum* rootstocks are available, it would be infeasible to grow them as a cultivated crop.

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Alkaloid Yields of *Veratrum fimbriatum* as Influenced by Site, Season and Other Factors

Alkaloid content of Veratrum fimbriatum *is much greater during rapid growth in early spring than the rest of the year. Top growth at the expense of stored food reserves did not deplete alkaloids. Individual plants were in two categories regarding high or low percentage alkaloid producers.*

CARL A. TAYLOR[1]

Introduction

The chemistry and pharmacology of the *Veratrum* alkaloids have been investigated extensively, especially those of *V. viride* Ait., and some specific to *V. Eschscholtzii* A. Gray and to *V. fimbriatum* A. Gray were described by Klohs et al. (1, 2). However, the writer has not found any published information on the percentage yields of the crude alkaloid complex of *V. fimbriatum* nor of alkaloid yields of *V. viride* as influenced by environmental or other factors.

Native mature plants of *V. fimbriatum* were used for the investigations reported herein. The choice of species was dictated by the availability of material. Populations of this species grow within 200 miles of the laboratory, whereas the nearest stands of *V. viride* are several thousand miles distant, and periodic sampling would involve prohibitive travel costs. Periodic sampling from different types of sites and assays of the plant fractions contained experimental error associated with non-specific environmental factors. However, consistency of those differences on periodic sampling would tend to confirm that the differences are real and probably associated with the site conditions involved. Also it is useful to know that the distribution of the alkaloids within the plant and the seasonal fluctuations are characteristic of the species, persisting in spite of environmental effects.

The preceding article (3) in this issue of Economic Botany describes cultural requirements of *Veratrum* which made growing plants under different controlled conditions impractical. That report also describes certain features of morphology and ontogeny which justified looking for alkaloid differences associated with plant age and flowering.

Experimental Methods

Mature plants were harvested at different kinds of sites at three periods during the growing season. The plants were dissected for separate testing of parts, such as leaves, crown buds, roots and rhizomes. Individual plant data were recorded as to their size, age, number of new and old roots, their history, such as frequency of blooming and whether destined to bloom next year, and incidence of vegetative increase by forming more than one crown bud. Much of the data are omitted from this report because the alkaloid percentages were not correlated with those conditions.

The data are coded with Roman numerals for plant groups dug from a given

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site, letters for plant parts, and Arabic numerals for individual plants or clonal clumps.

Sites

Groups I, II and V were dug from a pasture along the south bank of the Gualala River near its mouth, in the extreme northwest corner of Sonoma County, California. It is a treeless meadow bordered by timber, in which *V. fimbriatum* also flourishes. The soil is a yellow fine textured silt-loam. The site is wet and occasionally flooded in winter and early spring, becoming dry in summer. By August the soil becomes very dry and hard; soil samples from the upper six inches were a little below the wilting point. A site so dry much of the summer is uncommon for *V. fimbriatum*, but the species apparently thrives here, as the colonies were extensive. The foliage dies down in mid-July, however, as it does in all sunny sites regardless of moisture supply, and the leafless stalks lengthen and bloom, setting copious seed in November and December.

Under the conditions of this site, the rhizome material with its annual accretion of new roots at the top persists for nine to ten years. Crown diameters were relatively large, averaging 1⅛″ diameter, though the hour-glass shape of some of the rhizomes indicated earlier cycles of adversity. Roots were thick and bright yellow. Lateral rootlets forming late in the current season or early in the second season persist for several more years, then disappear, leaving the old roots up to nine years of age apparently functional but unbranched. Incidence of blooming was relatively high at this site, though sampling was not great enough to give a reliable percentage. Frequency of crown doubling was somewhat ambiguous. In one harvest of mature but single plants, about three-fourths of them contained twin buds for next year's growth; but in a later harvest of clumps which had arisen from earlier series of crown doubling, most of the crowns contained a single new bud destined to form the following year's shoot.

Site III is extremely wet. It is a few miles north of Fort Ross, at Ocean Cove Ranch, about 23 miles down the coast from Gualala, and is the extreme southern range of the species. The soil is a black plastic clay, saturated so that anaerobic conditions prevail. It has the odor typical of anaerobic soils, and the roots were stained with precipitated iron. It has reaction of pH 6.8.

Under these conditions, *V. fimbriatum* plants have survived for decades but with limited growth. The plants were present mostly as large clumps accruing from crown doubling in occasional years. They grew in sun except for shading by rushes and tall grass.

Site IV, a few miles north of site III, is a sunny southwest slope with soil of black, highly organic, coarse sandy loam, the topsoil friable and free draining but saturated in early summer because of claypan beneath. The occasional large clumps of *V. fimbriatum* were obviously very old. They each contained 20 or more short shoots, non-flowering and borne on cylindrical rhizomes only about one-half inch diameter and clothed with roots more slender than normal for the species.

Site VI was judged to be an optimum site. It was a wooded bottomland along the Little North Fork River about one and one-fourth miles upstream from its confluence with the Gualala River (several miles east of site V), where plants of *V. fimbriatum* of all ages grew in profusion. The soil was yellow gravelly silt-loam mixed with woody debris from periodic floods. In this and similar shady sites, the plants produce tall stalks with very large succulent leaves, and the tops remain green until the fruits ripen in November and December. The plants growing here had roots one-fourth inch

diameter produced in numbers averaging six per crown per year and better supplied with laterals than those of the unfavorable sites. Crown diameters averaged 1.2 inch; and many of the rhizomes were V-shaped, indicating rapid annual increase of crown diameter.

Site VII was a transplanting site at Moss Landing, in coastal Monterey County, California, to which mature plants had been moved from site I a year and a half earlier. As grown under artificial shade and irrigation, they thrived and were assumed to be comparable to the native plants. Seedlings grown at the same site also were tested.

Harvest Groups

Groups I and II were dug March 4 and 5, 1952, when the folded shoots were just emerging above ground. In group I the crowns were severed at the top of the rhizomes and the rootstocks held in a box covered with burlap. When processed in May, the roots were in various stages of drying, but many were still quite plump. The group II plants were left with crown buds attached and held in shade, covered with moist sphagnum moss. There they made good top growth from their stored food reserves and water only—in fact, the tops were darker green and possibly larger than others with longer roots which had been planted in soil. The purpose of these treatments was to determine whether depletion of food reserves by top growth also depletes alkaloids. Group I made no top growth because the crown buds had been removed.

Sites III, IV, V and VI were sampled in mid-May when leafy tops were fully developed but before flower stalks had appeared. At this time the new fleshy unbranched roots had developed sufficiently to provide a limited supply of very young root material.

Six plants or clumps were chosen from site III.

Two clumps containing 22 and 23 shoots, respectively, were dug at site IV.

At site V (the same as I and II) the harvest consisted of nine single-crown plants, one with double and one with triple crowns; also two large clumps. The latter clump (designated as #16 in the table of yield data) had 16 stalks arising from multiple branched rhizome.

Site VI also was sampled by nine single-crown plants, one double and one triple crown.

Sites III, V and VI were again sampled July 10th, 1952, at which time dieback of the leaves had started at the sunny sites. Flower stalks were well developed, bearing closely bunched flower buds which would later become spaced out by lengthening of the internodes of the panicle.

Two clumps were taken from site III, the first having 13 stalks with leaves brown about one-third of the way back from their tips—from partial shade. The second clump from full sun, had 41 short non-flowering shoots. Leaves all brown.

Two clumps were harvested from site V and bulked. The soil here was very dry, but the foliage remained greener than in the plants from the very wet site III. Each of the seven stalks bore flower buds. Five of them were on persistently single crowns, each containing one new crown bud for next year.

At site VI, three classes of plants were chosen: *a*) three large "virgins", apparently never having borne; *b*) three large "primaparas", persistently single crowns bearing for the first time; and *c*) a "matron" clump of nine stalks, three of which were flowering; the branched condition of the rhizome gave evidence that the plant had bloomed for at least six years.

In view of the high percentages of alkaloids in groups I and II, it seemed advisable to verify that the results were not some artifact of the long delayed

processing of those samples. Therefore plants of several ages and locations were sampled from several sites in late January and February of the following year. They were:

VII. Five plants from Moss Landing, Calif., where they had been moved from site V a year and a half earlier. Their crown buds were extended slightly above ground when dug. They had bloomed the previous summer, three of them having formed double crowns and one a triple crown.

VIII. One hundred thirty two-year-old seedlings grown at Moss Landing were included in the January 1953 sampling. Also seed of *V. fimbriatum* which had been kept stratified at low temperature since its collection in November.

Site VI was resampled in February 1953, taking 12 plants. They were medium to large single-crown plants—seven " virgins " and five " matrons ".

All of the previously described groups of plants were sectioned into the parts coded below. In some instances several of the parts, and in some cases the same part from all of the plants of a group, was bulked to make sufficient material for replicate assays. However, the new roots and the previous year's roots were tested by individual plants.

N—New roots, produced during the current season.

A—Last year's roots.

B—Roots two years old or older (1950 and previous).

C—The top half inch of the rhizome—the younger tissues.

D—The bottom ¼" of the rhizome—the oldest tissues.

E—The central portion of the rhizome—intermediate aged.

F—Cortex from the central portion of the rhizome.

G—Stele, or xylem and phloem from the central part of the rhizome.

H—Crown bud or basal inch of the stalk—no rhizome tissue.

I—Tissues in the vicinity of the growing point at the top of the rhizome.

J—Three-inch section of the stalk immediately above " H " (growing underground).

K—Leaves, including their sheathing bases down to J.

L—Stems—semi-woody (from flowering plants).

When several of the parts were combined, the coding so indicates, i.e., CE for entire rhizomes or A–E where roots and rhizomes of seedlings were combined.

Sample Preparation

After thorough washing, the plants were dissected, the respective parts were thinly sliced and chopped, then dried in forced draft at 60° C. All except the smallest samples were ground first in a small Wiley Mill, then pulverized in a Raymond laboratory hammermill. The pulverized samples were held in sealed jars in darkness until assayed. Moisture contents of most of the samples were in the range of 4% to 7%, and the results are reported on sample weight basis.

Nearly all of the samples were first assayed by a turbidimetric method, wherein ammonium molybdate was added to filtered acetic acid extract of the sample material. The resulting turbidity was read in a specially designed photometer. However, the turbidity so produced was found to be influenced greatly by non-alkaloid substances. Those substances were present rather proportionally to the alkaloids, but the correlation between turbidity and alkaloid content was not close enough for more than estimates of the alkaloid percentages.

The gravimetric method adopted required larger samples than could be tested turbidimetrically, so more of the samples had to be grouped than was originally intended. Briefly, the method was to extract one gram of the ground

sample with 5% acetic acid, filter the extract, titrate with NaOH until pH was 7.2 (± 0.1); then extract with chloroform, evaporate the chloroform and weigh the amorphous crude alkaloid mixture. Reproducibility of results was such that differences greater than 7% between duplicate means exceed the 5% level of probability.

Obviously the crude alkaloid recoveries do not indicate accurately the percentages of pure alkaloids present, but on the basis of unpublished work at the Riker Laboratories, it is believed that they suffice for comparison of the different plant groups and their respective parts.

Results

Water Contents. Fresh and dry weights were omitted from this report but some comment is justified. At the beginning of growth in early spring, water content of all parts of the plants was high and variable among the parts and between locations. At that season the fresh/dry weight ratios of crown buds and previous year's roots were in the range 5.5 to 8, and of rhizomes 3.7 to 6.5.

In summer, when the plants had completed the rapid phase of top growth, ratios were much lower and not greatly affected by available moisture. In July, plants dug from a very dry sunny site had F/D ratio approximately 2.8 in all underground parts. At the same time plants from a very wet sunny site had F/D ratios in their crown buds 2.7 to 2.8, roots 3.9 to 4.4, and rhizomes 3.35. Similar ratios were present in plants from a moist shady site where tops were still lush. In a September harvest all underground parts had average F/D ratio of 3.35. The fleshy appearance of the crown buds belied their water content which was as low as or lower than in the roots and rhizomes.

Crude Alkaloid Yields. Table I summarizes the assays made. The data are inadequate for conclusive answers to many of the questions involved, but the effect of several factors is quite clear. In early spring, when the plants were just coming up, the percentage contents of substances testing as alkaloids were nearly twice as great as in the following July. Sampling was not frequent enough to show the rapidity of the drop from early March to mid-May, but there was some indication that the percentage drop continued moderately from May to July and was more pronounced in the sunny sites where the tops die down earlier than in shade.

Perhaps the disappearance of alkaloids during the spring growing season is somehow associated with root activities. The plants dug in early March and held until May under conditions wherein no root growth occurred, had alkaloid contents typical of the digging season, regardless of whether or not tops were produced.

The variability of alkaloid yields among individual plants dug at the same site and season was great enough to cancel out significance for site influences or the reproductive status of the plants. This was suspected to be genetic variability but was not proven. The previous year's roots from 11 single plants from each of the sites V and VI and six clumps from site III were assayed turbidimetrically. Then the residual materials from the samples comprising the sub-group means below were assayed by the more accurate gravimetric method.

The 50:50 distribution ratio is puzzling. If high alkaloid yield were controlled by a single factor gene, the expected ratio would be 3:1. Of course the number of plants was rather small for interpreting the actual distribution.

Distribution of Alkaloids Within the Plant. To damp the effects of plant variability and gain a more general view of the distribution of the alkaloids, data

TABLE I

CRUDE ALKALOID PERCENTAGES OF PLANT FRACTIONS OF *Veratrum fimbriatum*

Groups and plants	"N" New roots	"A" Last yr. roots	"B" Older roots	"C" Rhiz. tops	"D" Rhiz. bases	"E" Rhiz. middle	"F" Cortex	"G" Stele	"H" Crown buds	"I" Meristem	"J"	"K" Leaves	"L" Stems	Plant averages: Without tops	Plant averages: Incl. tops
March '52															
I		2.45*	2.53	4.91	3.16	3.06*	4.23*	4.15*						3.20	
II		2.52	2.75*	4.59	3.90	3.92*			1.80*	2.40	1.27*	1.67*		3.24	2.43
VI (Feb. '53)		2.01*		(.....	4.06*	.....)			2.29*		2.03*	2.30*			
VII (Jan. '53)		2.28*	2.90*	(.....	3.17*	.....)			2.51*					2.71	
May '52															
III	2.05*	1.70*	2.07*	2.72	1.92	2.66*			1.25*			0.63*		1.54	
IV (1)	2.47	1.05	1.36	2.07	1.77	2.50*			0.70					1.41	
(2)	1.37	1.00													
V (1–11)	2.11*	1.45*	1.67*	2.90*	2.77*	2.53*			1.75					1.91	
(12–15)	1.90*	0.90*	1.44	1.89	(.....	2.19)			0.74					1.12	
(16)	1.69*	1.05	1.95*	1.92	(.....	2.31)			0.95					1.79	
VI (1–11)	2.35*	1.77*	2.10*	3.34	(.....	3.47*)	3.40	2.65	1.80					2.31	
July '52															
III (1)	1.17	0.64	0.54	(.....	1.42	.....)			1.01*		0.70*	0.80*	0.50	0.80	0.79
(2)	(.....	1.28	.....)	(.....	1.34	.....)			0.80		dead	0.17		1.18	0.97
V	1.30	0.88	0.86*	(.....	2.27*	.....)			1.09*		0.90	0.64*	0.79*	1.28	1.07
VI (1)	1.78	1.35	2.79	(.....	3.31*	.....)			1.66*		0.89	0.79*		2.41	1.40
(2)	1.73	1.35	1.83	(.....	3.70	.....)			1.27		0.86	0.87*	0.69	2.31	1.42
(3)	1.51	1.05	0.97	(.....	1.79*	.....)			1.72*		0.83	0.78*	0.57*	1.38	1.15
Jan. '53															
VIII sdlgs.		(.....	1.10*	.....	.....	)			1.95*					1.52*	
IX seeds 1.69%*															

Items marked * are means of duplicate gravimetric determinations; those not so marked were derived from conversion of replicate turbidity values.

TABLE II

PERCENTAGES OF CRUDE ALKALOIDS

Site III (May)		Site V (May)		Site VI (May)	
"Low"	"High"	"Low"	"High"	"Low"	"High"
(2) 1.14%	(1) 1.83%	(1) 1.19%	(2) 1.75%	(1) 1.19%	(2) 2.28%
(4) 0.95	(3) 1.65	(3) 1.38	(5) 1.72	(4) 1.20	(3) 2.10
(6) 1.14	(5) 1.90	(4) 1.44	(6) 1.95	(7) 1.32	(5) 2.17
		(8) 1.00	(7) 1.92	(8) 1.19	(6) 1.69
		(10) 1.47	(9) 1.78	(9) 1.20	(10) 2.17
		(11) 1.27		(11) 1.48	
Av. 1.08	1.79	1.29	1.82	1.22	2.08
G* 1.35	2.07	1.13	1.76	1.33	2.21

G* figures are gravimetric assay values of the combined residual samples.

In looking for a possible explanation other than genetic variability, it was noted that in the Site V group all five of the "high yield" plants were those in which twin crown buds had formed for next year, while five out of the six "low yield" plants contained single new crown buds. However, among the plants from Site VI, only one of the 11 plants contained a twin crown bud, and the ten single-bud plants had the same 50 : 50 distribution as to high and low yield and with similar magnitude of difference.

from groups harvested simultaneously at the several sites were grouped. Data on the very atypical plants from site IV were omitted, and also the July harvest from site III. Several extrapolations had to be made to cover missing items of data in the late January to early March harvests.

The alkaloids were most abundant in the rhizomes, next in new roots, then the roots aged two or more years, and slightly less in last year's roots. Crown bud alkaloid percentages varied in the range of one year and older roots. Leaves were much leaner in alkaloids than the underground parts but did con-

TABLE III

DISTRIBUTION OF ALKALOIDS WITHIN THE PLANT AT SEVERAL SEASONS

	Early spring (Feb.–March)			May			July		
	Alkaloid content, percent	Percent of the total alkaloids	Dry wt. as percent of total	Alkaloid content, percent	Percent of the total alkaloids	Dry wt. as percent of total	Alkaloid content, percent	Percent of the total alkaloids	Dry wt. as percent of total *
New roots	...	...	...	2.09	2.85	2.6	1.51	3.6	3.6
Last yr's roots	2.22	13.4	17.4	1.41	15.05	20.6	1.15	6.2	8.0
Older roots	2.66	25.6	27.4	1.95	35.5	35.0	1.15	31.9	42.0
Rhizomes	3.70	42.0	32.4	2.74	34.0	24.0	2.34	38.1	24.4
Crown buds	2.35	19.0	22.8	1.37	12.6	17.8	1.50	17.5	17.5
Underground stalks, 3"	...	...	...	...	...	...	0.88	2.7	5.6
Averages & totals	2.89	100	100	1.92	100	100	1.51	100	100
Leaves	...	...	...	...	...	...	0.75	24.0	48.4
Flower stems	...	...	...	...	...	...	0.74	7.6	15.5

* Total underground parts constitute the percentage base.

tain enough to be of some commercial importance, and the young shoots of early spring contained higher percentage alkaloids than was commonly found in the roots in summer. The alkaloids seem to be distributed throughout the rhizome; and the differences in new and old portions or between cortex and stele were not significant.

Summary

Veratrum fimbriatum plants dug during or shortly before initial top-growth in early spring contained nearly twice as high percentages of crude alkaloids as were found in similar plants dug in July. Rootstocks dug during the period of high-alkaloid content were held until May under conditions permitting no root growth but with production of large tops or no tops, with no apparent loss of alkaloids such as occurred under conditions of natural growth.

Relatively great variability with respect to alkaloid yield by individual plants appeared to be present with approximately 50:50 bimodal distribution.

Possible effects of environmental factors, age and reproductive activities were obscured by plant variability at the sampling magnitude employed.

Influences of moisture supply and shade on growth and survival are described.

Citations

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Utilization Abstracts

Rauwolfia. Of some 130 species in this genus, distributed in Central and South America, Africa, the Far East, India and Burma, and Hawaii, *R. serpentina* of the Indian sub-continent has achieved prominence in recent years in the treatment of hypertension and related ailments. More than 20 alkaloids have been isolated from the roots of this shrub which has for ages, according to ancient Sanskrit writings, been valued in India as an antidote to the bites of snakes and other poisonous reptiles and insects. The efficacy of the shrub in relieving certain nervous derangements is attested by the practice of the late Mahatma Gandhi regularly to drink a tea prepared from it to overcome nervousness and secure a good night's rest.

All supplies are still furnished by wild plants, and in 1954, the demand from the United Kingdom, America, France and Germany was so great that the Indian government imposed a temporary ban on exports in order to conserve supplies for local use. Exploitation of hitherto untapped areas, cultivation of the plants and investigations of related species offer the means of alleviating the shortage. Already large scale collecting of *R. vomitoria* roots in the Belgian Congo is reported. An article on *R. serpentina* is contained in the Oct.–Dec., 1954, issue of Economic Botany. (A. J. Feuell, *Colonial Plant and Animal Products 5(1): 1–33. 1955.*)

Quercetin. This flavanol, now extracted commercially from buckwheat and the Chinese scholar tree (*Sophora japonica*) as the rhamnoglucoside, rutin, is a non-toxic substance having antioxidant and physiological properties, and, along with other flavanoids, possessing vitamin P activity. It may be produced also by hydrolysis of the rhamnoside, quercitrin, obtained from the bark of black oak, and by conversion of the dihydroquercitrin in the heartwood and bark of Douglas-fir and in the bark of Jeffrey pine. (E. F. Kurth, *Ind. & Eng. Chem. 45(9): 2096. 1953*).

Apple Storage in Northern Greece

Inadequate storage space and the expense of processing fruit mean surplus crops in Greece, although nearby countries, such as Israel, do not produce apples.

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The province of Macedonia, in northern Greece, is the leading apple producing area in that small Balkan country. The crop is good and has been increasing in recent years because of new plantings and of an upswing in the use of insecticides, fungicides and improved varieties. With fertilizer slowly becoming more available to the peasants, and the struggling Greek Agricultural Extension Service helping with advice and guidance, further increases in the apple crop are bound to follow. A problem of increasing urgency is the disposition of the surplus crop which the fresh-fruit market cannot handle at harvest time.

The possible solutions, none of which is complete in itself, would include increased exports to neighboring Near and Middle East countries; processing of the crop either as canned products, or vinegar, the latter a practice presently banned by laws intended to protect the grape producer; increased consumption, which requires an educational program; and finally increased storage facilities.

Of these, the last two have received some encouragement under the American Aid Program. During the spring of 1953 an American home-economist conducted several apple-pie baking schools that were well-attended; the E.C.A. has helped finance some new cold storages.

The latter method is particularly appealing to the grower because he is relieved of the burden of storing his crop in his own home.

The number of storages in northern Greece is small, probably not more than 12. Under E.C.A. three new ones have been built in recent years, in Verria, a mountain village in the center of the apple-producing area; in Salonika, largest city of northern Greece and second largest in the country; and in Kavalla, an important northern seaport.

In Salonika there are four cold storages; of these, "Macedonia", built in 1927, is probably typical. It has floor space of 172,800 square feet and a capacity of 50 to 70 tons of fruit. Refrigeration is provided by an odd assortment of American (Carrier), German, Dutch and English machines, all kept in excellent working condition.

Insulation is provided by pressed cork imbedded in cement walls. Curiously, each of the cold rooms has at least two round windows, consisting of a single pane of glass, a source of weakness in keeping the temperature down efficiently. Each room is entered through a series of two well-insulated doors.

Recently efforts have been made to move the air around in the cold room by means of large portable fans, made in Germany. Unfortunately the fans are not directed so as to move the cold air into the stacks but simply to circulate the air between the rooms. However, eventually an improvement in keeping conditions will result, with a consequent upgrading in the quality of fruit.

Apple storage begins in August, when merchants and brokers go into the

villages to buy the crop which is then moved to Salonika and Kavalla by means of trucks and trains. It receives only the barest hint of grading in the field, which eliminates only the most grossly damaged fruits. Thereafter no further grading is attempted. No grading as to size or color is ever attempted, nor are there any legal requirements for any. Washing or cleaning apples to remove spray residues is an unknown practice, and the Greeks wisely peel all apples before eating them.

Quite often apples are harvested and piled in the orchard for some time before packing, resulting in a high percentage of sunburn. As prices are rigidly fixed by the government, and no note is made of such defects, there exists no incentive to take care of the crop and to produce high quality fruit.

The fruit is packed in two types of containers—one is an oblong bushel basket, the other a half-bushel lug-type box. The latter is so built as to be stacked with a very generous air-space between boxes. Individual apples are never wrapped, but each container has a sheet of paper placed in it before the apples go into the box. The paper is purely ornamental, and untreated to minimize scald, contrary to the custom in America. The apples are jumble packed.

The most desirable storage varieties are, in their order of quality after storage, Delicious, Starking, Belfour and what are called "American" apples—small, well-colored fruits strongly resembling Stayman Winesap. Scald is relatively rare, the most important defect being the appearence of black spots after three or four months storage, resembling lenticel spotting.

Apples are stored by the middlemen who rent space at an American equivalent of about four-tenths cent per pound per month.

The usual storage temperatures for apples range from 33° down to 25.6° F.; for pears and peaches it varies between 32° and 35.6° F. Humidity is kept as close to 90% as possible by the use of a mist spray. Before the storage season begins sulfuric acid washes are used for disinfection.

Nothing is known about controlled atmosphere storage in northern Greece; copies of Cornell bulletins were presented by the author to the manager of cold-storage "Macedonia" for translation and dissemination.

Papermaking Fibers

True paper, in the technical sense of the term, was first made in China in 105 A.D. from the bast fibers of paper mulberry and probably also from bamboo. For many centuries old rags, principally cotton or linen, supplied the papermakers with raw material. In modern times, sprucewood fibers have long been outstanding for papermaking. In recent decades, however, the spruces have been equalled, if not surpassed, in tonnage used, by various species of pine, especially the southern yellow pines. Of secondary importance have been the fibers of dozens of other species.

IRVING H. ISENBERG [1]

Introduction

" Paper ", when used as a general term, is the name for all kinds of matted or felted sheets of fiber (usually vegetable, but sometimes mineral, animal or synthetic) formed on a fine wire screen from a water suspension.

The uses of paper are numerous (some 7,500 are claimed), but perhaps the two most familiar to the layman are in the recording of ideas in one form or another on it and the use of it or of paperboard for packaging purposes. According to estimates, the world consumption of paper products was 57 million tons in 1954.

Early History

Paper has not always been the medium that man has used on which to record his thoughts. The walls of caves served this purpose for primitive man. Bark, bricks, ivory, lead, leaves, shells, skins, stones, wax and wood were also used later. Scripture records that Moses took down the Ten Commandments upon tablets of stone.

The manufacture of paper appears to have begun in China about a century after the start of the Christian era. Historians credit its invention to Ts'ai Lun in 105 A.D. Originally the stalks of the plants utilized were disintegrated manually in a mortar after soaking. The beaten pulp was transferred to a vat, and sheets were made by dipping out some of the pulp on a mold with a reed bottom. Bast fiber of the paper mulberry (*Broussonetia papyrifera*) was used principally, although bamboo is mentioned by some writers.

Prior to this invention by the Chinese, a vegetable fibrous material had been in use for centuries by the ancients. This writing sheet was made by pasting together thin sections of the pith of an Egyptian sedge (*Cyperus papyrus*). Papyrus—from which our modern word " paper " is derived—is known to have been used as early as 2,400 B.C. It served as late as the tenth century after Christ when parchment prepared from the skins of goats, sheep and other animals was much used and paper began to appear in Europe. Actually the importance of papyrus started to decline in the seventh century when Egypt was conquered by the Arabs.

The manufacture of paper began its movement westward shortly after its invention, and three decades later (137 A.D.) it was being made in Tunhuang. Apparently bast fibers of the genus *Boehmeria* came into use during the third century. By the beginning of the fifth century paper was being made in

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Turfan in Chinese Turkestan. The Chinese built a mill at Samarkand in Russian Turkestan in the following century. One significant result of the capture of Samarkand and its artisans by the Arabs in 704 A.D. was the rapid expansion of papermaking to the eastern rim of the Mediterranean basin. A mill was built in Bagdad in 795 A.D. and in Damascus shortly thereafter. The Arabs made paper from linen rags or perhaps from the bast fiber of flax (*Linum usitatissimum*). Papermaking spread relatively rapidly across North Africa, thanks again to the Moslems. Paper was made in Egypt in 900 A.D., more than three millenia after the earliest known use of papyrus for writing material. The Moors made paper in Toledo, Spain, in 1085, in Xativa in 1154, and in Valencia soon afterward.

It has been stated that cotton seed hair was not used for papermaking either during the Arabian or the pre-Arabian period, although there may be disagreement concerning this point. It has also been stated that the earliest European paper made from cotton was in 1102. Allegedly the Spaniards found cotton rags to be better suited to papermaking than the raw fiber. They also used bast fiber from common hemp (*Cannabis sativa*) and flax and even linen from old mummy cloths. Certainly they were the first to turn the stamp mills with water power.

By 1189 papermaking had reached France (Essonnes or Herault) and in the early 14th century, Germany (Cologne and Mainz). Presumably the Italians acquired the art during the 13th century. In 1494 a mill began operation in England, but it is evident that papermaking spread much more slowly there in the 16th century than it did in China in the second century.

In the New World, early Spanish accounts record that the Aztecs made paper from *Agave* fibers. Agave paper, however, was reserved for special documents, and the paper in general use was prepared from the bark of a *Ficus* plant. In the United States the first paper mill was built by William Rittenhouse in 1690, near Philadelphia; linen rags furnished the fiber.

Modern History

The invention of movable-type printing by Johannes Gutenberg in the middle years of the 15th century and the renaissance in Europe led to a greatly increased demand for paper, and eventually rags could no longer satisfy the requirements of the papermakers. Of course, developments took time, but the 18th century saw a renewed attack on the search for fibrous materials of use for papermaking. It was René Réaumur, the French scientist and inventor, who, in the early part of the century, observed how the wasp built its nest. In the latter part of the century Dr. Jacob Christian Schaffer, a German pastor, experimented with many types of vegetable fiber, wasp nests, hemp, bark, straw, corn husks and even a few species of wood. Mathias Koop, in England, was the first to use vegetable fibers on a commerical scale and in 1800 published on paper made solely from straw and wood. In the United States the first straw paper was manufactured in 1828 by William Magaw of Pennsylvania.

Groundwood pulp was made about 1840 by Friedrich Keller in Germany. Soon afterward Burgess and Watt, Englishmen, built a mill in Manayunk, Pennsylvania, where wood was pulped by the soda process according to a patent granted in 1854. A patent for pulping by the sulfite process was granted to Benjamin Tilghman after the American Civil War, but it remained for Carl Ekman, a Swede, to perfect the calcium bisulfite process commercially. In a few more years Carl Dahl, also a Swede, invented the sulfate, or kraft, process.

The use of wood as a source of raw material for papermaking fiber was definitely on the upswing.

Such use grew rapidly until presently 95% of the pulp produced in the world is made from wood, and there is no indication that the dominance of wood pulp is declining, despite alarming predictions, repeated at various times during recent decades, that the world's pulpwood resources are on the verge of depletion. Certain other raw materials, however, continue to be utilized because they yield pulps of intrinsic value; conversion of esparto into high-class printing papers in Great Britain and of flax straw into cigaret tissue and bank-note paper in the United States and Canada may be cited as examples. Many other raw materials are technically capable of yielding usable pulps, since it has been truly said that pulp and paper can be made from any fibrous plant. The vital question, of course, is whether new material can compete with wood pulp in price and usefulness and hence find a ready sale on the open market. It might be feasible in certain situations for other materials to be used to supply a small integrated mill making paper for local consumption, especially if such a mill could be given tariff protection. Nevertheless, although the number of species studied for papermaking is considerable, only relatively few are at present relied upon.

At this point it may be well to emphasize the essentials in any material proposed for papermaking. The raw material must be abundant and consistently available. Growth must be in close proximity to economic labor supplies and ample water supplies of suitable composition. Convenient transportation should be available. The raw material must possess an appropriate fibrous structure and yield a comparatively high percentage of cellulose, while it must be of no serious commercial interest to any other industry.

Literally hundreds of plant species have been studied as possible sources of papermaking fibers. Broadly speaking, any fibrous plant can be pulped and made into paper or board. The limiting factor is sometimes economic, sometimes technical. Perhaps the cost of producing a competitive sheet of equivalent grade is too high to compete with sources already employed. But progress continues, and as the demand for paper products rises in the countries newly industrialized and those yet untouched by scientific advance, new sources of fibrous raw materials must surely be tapped.

Pulping Processes

Groundwood. This type of mechanical wood pulp is produced by pressing short barked and cleaned logs sideways against a revolving natural or artificial pulpstone in the presence of water, thereby reducing them to a fibrous mass of short fibers. The various uses of groundwood pulp are determined by important physical properties such as freeness, relative length of fiber, uniformity of fiber length, strength, color and cleanliness, which are determined by the coarseness or fineness of the pulpstone used, the dressing of the stone surface, the method of grinding, the character of the wood, and the screening of the pulp.

Chemical Methods. In the usual manufacturing procedure for chemical wood pulps, the barked and cleaned logs are reduced to chips, after which the chips are screened to eliminate oversized and undersized chips. The accepted chips are then subjected to chemical treatment which dissolves most of the ligneous binding material (lignin), leaving the fiber, which may or may not be bleached before use.

Fibrous raw materials, other than wood, which are to be pulped are usually cut to proper size.

SULFITE. In the sulfite pulping process the chips are digested at temperatures from 130° to 150° C. in an aque-

ous solution containing alkaline-earth bisulfites (usually calcium bisulfite or a mixture of calcium and magnesium bisulfites, although soda base, ammonia base and magnesia base liquors are suitable) and an excess of sulfur dioxide. The cooking procedure may be varied to produce pulp that can be roughly classified as weak, medium or strong, corresponding in large measure to the degree of lignin removal and the degradation of the cellulose of the fiber.

SULFATE OR KRAFT. In the sulfate or kraft pulping process the chips are digested at fairly high temperatures (170° to 180° C.) in a liquor which is a mixture of caustic soda and sodium sulfide in proper proportions. The pulps are used for the most part in the manufacture of the strong grades of the various classes of paper and paperboard.

SODA. In the soda pulping process, the active cooking agent is caustic soda, and the digestion takes place at fairly high temperatures (170° to 180° C.).

SEMICHEMICAL. A semichemical pulping process is so-called because only a part of the ligneous portion of the wood is removed during cooking. High yields result. After cooking, the softened chips are mechanically disintegrated by a suitable type of refiner. The term "semichemical" is not specific to any of the chemical pulping processes. However, probably the principal type of semichemical pulping is the neutral sulfite process, which uses a liquor of sodium sulfite buffered with sodium bicarbonate.

CELDECOR-POMILIO. The soda-chlorine process of Pomilio involves four chemical operations: alkaline pretreatment, gas chlorination, alkaline wash, hypochlorite bleach.

Species Used in Various Countries

We can learn a great deal of the pulp, paper and paperboard industry by considering the various fibers now used in the manufacture of this essential commodity in the countries of the world.

United States. The United States is an appropriate place to begin our discussion because it is by far the greatest consumer of paper products in the world, using, as it does, about 415 pounds per person annually.

In 1954 the United States consumed 19.8 million tons of wood pulp, 8.1 million tons of waste paper, and about 1.2 million tons of other fibers. It was the principal chemical woodpulp-producing country and second only to Canada in the production of mechanical pulp. The consumption of pulpwood in 1954 was 29.2 million cords, of which 85% was softwoods and the remaining 15% was hardwoods. An appreciable portion of this softwood is imported from Canada, as is much of our newsprint.

Three-fifths of our domestic pulpwood is produced in the South, and of this about 90% is southern yellow pine. Loblolly pine (*Pinus taeda*) is the principal species, but shortleaf, slash, longleaf, pond, spruce, sand, Virginia and pitch pines are processed in varying amounts. In the North the conifers used for pulp are black, white, red and Engelmann spruces; balsam fir; eastern hemlock; jack, red or Norway, lodgepole and white pines; and tamarack. In the West the softwoods pulped are western and mountain hemlocks; grand, white, silver and noble fir; Douglas-fir; western larch; lodgepole, ponderosa and western white pines; Sitka and Engelmann spruces.

A new mill recently completed in southeastern Alaska consumes principally western hemlock and Sitka spruce.

The broadleaf species of paper-pulp value in the United States are aspen (both trembling and largetooth); balsam poplar and various cottonwoods; black, water and swamp tupelo; sweetgum; red, silver and sugar maples; yellow and paper birches; yellow poplar; cucumber; evergreen magnolia; sweetbay; beech; chestnut; several species of oak; buckeye; basswood; elm; ash; red alder; and ailanthus. Increased demand for pulp-

wood and new developments in both pulping processes and products, may permit greater use in volume as well as percentagewise in the near future.

Fibers other than wood used in this country in the manufacture of paper are chiefly wheat straw, cotton and linen rags, cotton linters, linseed flax, sugar cane bagasse, abacá (Manila fiber), sisal, jute, sunn and common hemp. There may be insignificant amounts of other vegetable fibers. Frequently wool fiber is part of the furnish in saturating papers, and mineral and synthetic fibers enter certain grades.

Without question there are vast tonnages of agricultural residues which can furnish fiber to the paper industry if and when conditions warrant. There is considerable exploration in progress on these sources as well as on species of wood not listed above.

Canada. Canada is the world's largest producer of mechanical pulp, most of which goes into newsprint, of which she is by far the chief source of supply. Canada is also the second largest producer, after the United States, of chemical woodpulp. The Canadians use 280 pounds of paper products per person annually.

The principal softwood pulp species in Canada are black, Engelmann, red, Sitka and white spruces; jack, red or Norway, white, lodgepole and ponderosa pines; eastern and western hemlocks; balsam, silver, grand and noble firs; Douglas-fir; western red-cedar; and tamarack. The hardwoods are aspens; balsam poplar; northern black cottonwood; red alder; white and yellow birches; hard and soft maples. Fibers other than wood are chiefly wheat straw; cotton and linen rags; linseed flax; and some of the so-called rope fibers.

Latin America. Our neighbor immediately to the south of the Rio Grande uses 17 pounds of paper per person annually, but the consumption is increasing and Mexico is opening new mills to meet the demand. True firs, pines (including ponderosa) and sugar cane bagasse are used principally; some eucalypts also. Thought is being given toward the exploitation of some of the mixed tropical hardwood stands in Yucatan and other areas.

The consumption of paper products in several Latin American countries is relatively small, the approximate number of pounds per person annually being: Cuba, 57; Uruguay, 50; Argentina, 44; Venezuela, 25; Chile, 22; Brazil, 19; Colombia, 12; Costa Rica, 10; Dominican Republic, 7; Guatemala, 6; Ecuador, 5; Honduras, 3; Bolivia, 2; Paraguay, 2; Haiti, 1. Most of this paper is imported, but there are several mills in South America. In late 1953 a meeting of pulp and paper experts was held in Buenos Aires to stimulate Latin American production.

The principal wood species used are Paraná pine (*Araucaria angustifolia*), poplar and eucalypts. A Brazilian mill is pulping mixed tropical hardwoods (as many as 60 species) by the semi-chemical process for unbleached pulp. Mixed tropical hardwoods are being studied in the pilot plant stage in Bolivia, and it is hoped that full scale production will start within three years. Fast-growing cetico (*Cecropia* sp.) wood in Peru has been shown to be excellent for groundwood, and future exploitation is anticipated.

The chief sources of domestic pulps, however, are wheat straw, rice straw, sugar cane bagasse, *Arundo donax* cane, and caroa (*Neoglaziovia variegata*). Costa Rica has a small pulp and paper mill converting abacá as the basic raw material into multi-wall bags. A small mill producing board from extracted lemon grass (*Cympogon citratus*) in Guatemala is operating at a fraction of capacity, and another in Trinidad

which depended upon bamboo has recently closed.

Europe. Following the United States and Canada in annual per capita consumption of paper are the European countries, particularly those of northern and western Europe. The following amounts in pounds are given: Sweden, 200; United Kingdom, 164; Denmark, 141; Switzerland, 141; Norway, 140; Finland, 124; West Germany, 109; Belgium, 108; Netherlands, 105; France, 84; Eire, 60. Other European states follow in this order: Austria, 69; Bulgaria, 45; East Germany, 45; Czechoslovakia, 40; Italy, 35; Poland, 35; Soviet Union, 25; Portugal, 17; Spain, 17; Greece, 15; Hungary, 15; Yugoslavia, 11; Rumania, 7. There is no correlation between these statistics and the production of pulp, paper or paperboard.

The northern countries of Finland, Norway and Sweden have long been pulp suppliers for many regions of the world. The number of species utilized (in fact, available) in these countries is few; the principal species pulped are pine (*Pinus sylvestris*), spruce (*Picea excelsa*), aspen (*Populus tremula*) and birch (*Betula pubescens* and *verrucosa*).

Other wood species pulped in Europe are true firs (especially silver), pines, larch, various hybrids of *Populus*, beech, chestnut, oak, and in countries such as Portugal and Spain, eucalyptus. Germany has become one of the foremost countries in the pulping of temperate hardwoods. About 70% of Italian pulpwood is hardwood, mainly poplar. A wide variety of other plants has been studied very intensively in several European countries, especially during wartime when imports must, perforce, be drastically reduced. One might mention, for example, the bast fibers from potato stalks and hop vines. Even peat has been examined for its pulping characteristics. Non-woody fibers actually in use include various cereal straws, esparto, *Arundo donax* reed, *Phragmites communis* reed, cotton, flax and hemp. It is said that tourists can purchase papyrus sheets made contemporarily in Sicily.

Australia. The people of Australia and New Zealand consume appreciable quantities of paper products, some of which are produced domestically. The annual per capita consumption is 130 pounds in Australia and 104 pounds in New Zealand. Several species of eucalypts, mountain ash (*Eucalyptus regnans*) and messmate stringy-bark (*E. obliqua*) in particular, are being pulped, and only recently a second large mill in New Zealand has begun production from radiata pine (*P. radiata*), a species introduced from California where it is known as Monterey pine. Minor quantities of other softwoods are used in Australia. New Zealand flax, or phormium fiber (*Phormium tenax*), is also pulped in at least one Australian mill.

Japan. The Japanese have been making paper for many centuries, but, although the Fourdrinier machine which increased the production of cheaper papers greatly, was invented in France by Roberts in 1796, it is only relatively recently that it has been used to any extent in Japan. The Japanese use the bast fibers from kozo, or paper mulberry (*Broussonetia papyrifera*); mitsumata (*Edgeworthia papyrifera*); and gampi (*Wikstroemia canascens*); and leaf fibers of abacá (*Musa textilis*) to make beautifully formed handmade sheets which find use in everything from houses to umbrellas and handkerchiefs to stencil tissues. Woods pulped in Japan are chiefly spruce, true fir and pine. Japan has been using increasing amounts of hardwoods, mainly poplar, since the war. The neutral sulfite semi-chemical process is used principally. Japan is now the fifth largest producer of chemi-

cal woodpulp and the sixth largest producer of mechanical woodpulp in the world. The annual per capita consumption is 47 pounds.

China. China, where papermaking originated, uses only 1.6 pounds per person per year, although Taiwan consumes 13 pounds and Hong Kong 35.

Rice straw, bamboo, sugar cane bagasse, hemp and cotton stalks serve for papermaking in China. Bleached pulp from bagasse is being made in Taiwan. Pulp is also made there from bamboo, rice straw, ramie, banana fiber, grasses, and from "hemlock" trees said to be four to five feet in diameter. Sheets of rice paper, resembling papyrus, are not made from rice straw but from the Taiwan plant (*Fatsia papyrifera*). The white pith is cut spirally into thin sections with a sharp knife, and these are laid next to each other, slightly overlapping, to make sheets.

India. India, which requires only 1.9 pounds per person per year, has been increasing its domestic production of paper. The chief raw materials continue to be bamboo (several species, e.g., *Dendrocalamus strictus*) and sabai grass (*Eulaliopsis binata*). Secondary raw materials are rags, rope cuttings, hosiery cuttings, waste paper and imported woodpulp, but other sources are now entering the scene. One unit uses bagasse for coated board, and bleached bagasse is being used for other purposes. Rice straw (*Oryza sativa*) is made into strawboard. Eta reed is also pulped. Newsprint has been manufactured from a mechanical pulp prepared by grinding salai wood (*Boswellia serrata*) and a bleached bamboo kraft pulp as the chemical fiber. Several other species of wood have been investigated at the Dehra Dun Forest Research Institute, but apparently sal (*Shorea robusta*) is the only other one processed at present. Himalayan conifers, such as *Picea morinda*, *Abies pindrow* and *Pinus longifolia*, could produce excellent pulps; the first two would make an excellent grade of groundwood. Jute, sunn and paper mulberry furnish bast fibers which might be converted into specialty papers if they are not so utilized already.

Other Asiatic Countries. With the exception of Japan which consumes 47 pounds of paper per person annually, the other nations of Asia have a very low annual consumption per capita: Philippine Islands, 10; Israel, 9; Turkey, 6; Ceylon, 3.7; Indonesia, 3.5; Iraq, 2; Thailand, 2; Pakistan, 2; Indo-China, 2; Burma, 1.3 pounds. The huge populations of many of these nations and of certain of their neighbors, especially in Southeast Asia, will constitute a vast potential market when the masses become literate and when industrialization increases. In the Philippines, bleached pulp is being produced from sugar cane bagasse by the Celdecor-Pomilio process. There is talk of producing pulp from certain of the lauan woods, from abacá and from large stands of pine in the mountains of northern Luzon.

In Pakistan bamboo (*Melocanna bambusoides*) and cereal straw are pulped, particularly in East Pakistan. With the possible exception of small amounts of handmade paper from *Wikstroemia viridiflora* and *Broussonetia papyrifera*, all paper products must be imported into Indo-China (Vietnam, Cambodia, and Laos). Two mills in Indonesia (Java) are producing pulp from rice straw. In Thailand bamboo (*Thyrostachys siamensis* and *Bambusa arundinacea*) and wood (*Tetrameles* sp., *Spondias* sp., and *Bombax* sp.) are pulped in limited quantities.

A mill in Turkey is pulping *Abies bornmuelleriana* and *A. nordmanniana*, *Picea orientalis*, *Pinus sylvestris*, poplar, aspen, willow, wheat straw and rag.

Africa. Known paper consumption in African countries is: South Africa, 34; Egypt, 11; Belgian Congo, 11; Algeria, 11 pounds per person annually.

Pulp is produced in South Africa from

bagasse, eucalyptus (*E. saligna*), wattle (*Acacia decurrens*) and spreading-leaved pine (*Pinus patula*), an exotic introduced from Mexico. Straw pulp was manufactured for a time but eventually the supply of wheat straw proved inadequate. Latest reports indicated that local pines are ground into mechanical pulp in Southern Rhodesia.

Algeria, the source of much of the esparto grass used in pulping in Great Britain, Italy and France, is now producing some of this pulp itself and incorporating it into sheets with wheat straw pulp. A board mill in Morocco uses local cedar (*Cedrus atlantica*) and eucalypts in conjunction with imported materials. In Egypt cotton fibers and rice straw have gone into paper. A bagasse mill is in the development stage. In view of the large supply, papyrus stems have received consideration as a possible source of pulp but have not been used to any great extent, apparently because of the large volume of pith (over 80%). A somewhat high consumption of chemical was necessary and the resulting paper was rather hard, rattly and translucent. It is somewhat doubtful, however, that the price obtainable for this product in competition with the superior materials already available would be sufficiently high to render its production remunerative. In Uganda one small mill is using papyrus for the manufacture of board for local use. In Tanganyika a factory has been erected to extract fiber from the baobab or monkey bread tree (*Adansonia digitata*). It is reported that a bagasse mill is under construction in Angola. Wattle is pulped in Southern Rhodesia.

The French Government, through the Regie Industrielle de la Cellulose Coloniale, has erected a modified soda (soda-sulfur) pilot plant capable of pulping 6,000 tons annually from rain forest tropical hardwoods in the Ivory Coast, French West Africa. To be economically feasible, a pulp mill must produce about ten times this amount. As the local market is very small in many tropical areas and probably will be so for some time, the production must be directed toward the markets of countries with high industrial potential.

Survey by Families and Genera

The first part of this article has considered rather briefly the species used in making pulp, paper and paperboard in various countries of the world. Under present world conditions it is difficult —sometimes impossible to get accurate or complete information on raw materials.

In this section the information on papermaking fibers has been summarized for the reader by considering them by family and genus. Only seed-bearing plants are involved.

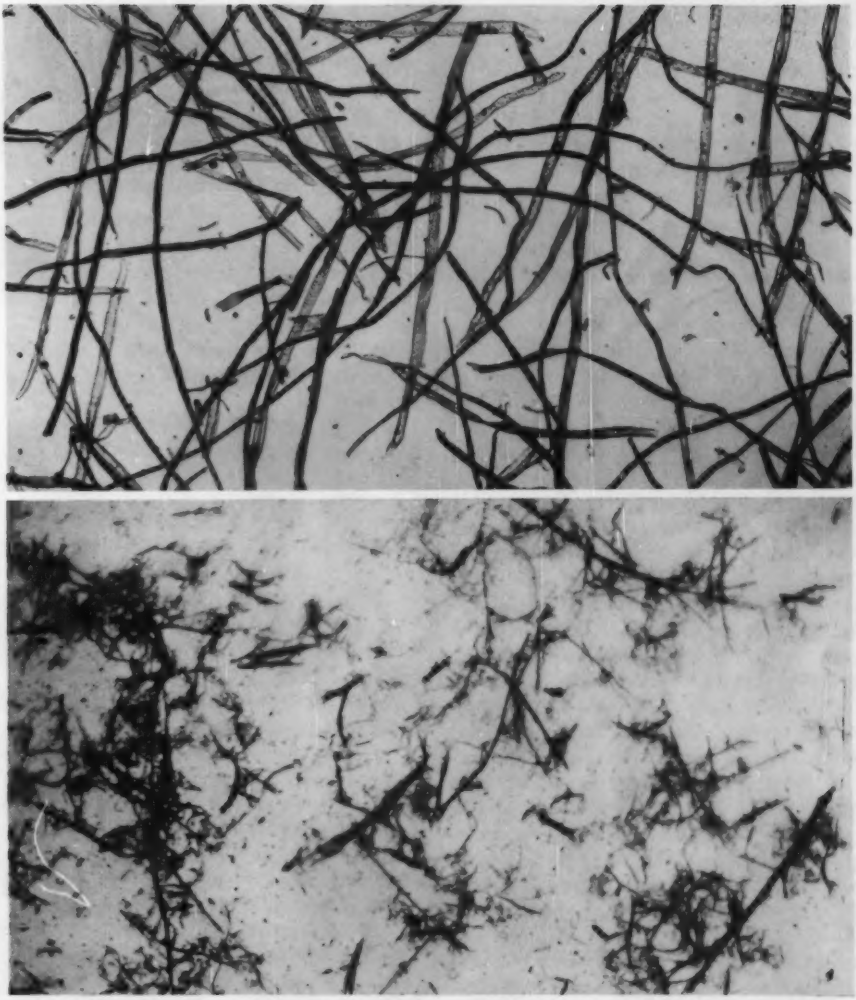
GYMNOSPERMAE

Coniferales

Pinaceae

Pinus. A large percentage of the sulfate (kraft) pulp made from wood is produced from various species of this genus. In Europe the principal source of supply in many countries is Scotch pine (*P. sylvestris*). Maritime, or cluster, pine (*P. pinaster*) is made into kraft pulp in France, Portugal and Italy. Corsican pine (*P. nigra calabrica*) and Swiss mountain pine (*P. montana*) are also pulped in Italy.

In North America, loblolly pine (*P. taeda*), shortleaf pine (*P. echinata*), longleaf pine (*P. palustris*), slash pine (*P. caribaea*) and jack pine (*P. banksiana*) are the chief sources of supply, but Virginia pine (*P. virginiana*), lodgepole pine (*P. contorta latifolia*), ponderosa pine (*P. ponderosa*), pitch pine (*P. rigida*), pond pine (*P. rigida serotina*), spruce pine (*P. glabra*), sand pine (*P. clausa*), eastern white pine (*P. strobus*), western white pine (*P. monticola*) and certain Mexican pines, probably *P.*



Two of the principal wood-pulp fibers of the United States. Upper: Southern pine (*Pinus* sp.) ×25. Lower: Spruce, groundwood (*Picea* sp.) ×15.

montezumae and *pseudostrobus*, are used.

Monterey pine (*P. radiata*), although not pulped in its native California, grows rapidly and is pulped in both Australia and New Zealand, where it is commonly known as "radiata pine". It is also grown and pulped by the groundwood process in Chile. Similarly, the spreading-leaved pine (*P. patula*) indigenous to Mexico is cultivated and used in South Africa. Akamatsu, or Japanese red pine (*P. densiflora*), is probably pulped in Japan.

Larix. Small amounts of several species of this genus are pulped by the sul-

fate process. Tamarack (*L. laricina*) and western larch (*L. occidentalis*) are used in the United States and Canada, and European larch (*L. decidua*) in several countries of Central Europe.

Picea. This genus is probably the most universally favored for pulping because the wood combines the desirable qualities of light color, relatively low pitch content and long fiber. It produces an excellent groundwood, sulfite or sulfate pulp. Many papermakers have fervently shouted—"spruce is king!"

Norway spruce (*P. excelsa*) is widely used in northern Europe. In Canada and the United States, black spruce (*P. mariana*), white spruce (*P. glauca*) and red spruce (*P. rubens*) are favorites, and Sitka spruce (*P. sitchensis*) and Engelmann spruce (*P. engelmanni*) are used as much as possible. The Japanese make pulp from several species, namely: ezomatsu (*P. jezoensis*), tohi (*P. hondoensis*), iramomi (*P. bicolor*), akaezo (*P. glehni*) and harimomi (*P. polita*). *P. orientalis* is used in Turkey.

Pseudotsuga. Douglas-fir (*P. taxifolia*) is pulped by the sulfate process in the United States and Canada.

Tsuga. Western hemlock (*T. heterophylla*) is the most important pulping species in the Pacific Northwest region of the United States and Canada. Some mountain hemlock (*T. mertensiana*) is undoubtedly mixed with western hemlock in the mill. Eastern hemlock (*T. canadensis*) is pulped in both countries also. The Japanese pulp *T. sieboldii* and *T. diversifolia*.

Abies. Various species of this genus are manufactured into groundwood, sulfite and sulfate pulps. Balsam fir (*A. balsamea*) finds considerable use in eastern North America. In the Pacific Northwest, grand fir (*A. grandis*), white fir (*A. concolor*), noble fir (*A. procera*), red fir (*A. magnifica*), amabilis fir (*A. amabilis*) and alpine fir (*A. lasiocarpa*) are utilized.

In central Europe, silver fir (*A. pectinata*) is used appreciably. In Mexico, sacred fir (*A. religiosa*) is pulped, and in Japan so are *A. firma, homolepis, mariesii, mayriana, sachalinensis* and *veitchii*. In Turkey, *A. bornmuelleriana* and *A. nordmanniana* are pulped.

Taxodiaceae

Sequoia. Some redwood (*S. sempervirens*) is reduced to fibrous material by the Masonite explosion process. The bast fiber has been formed into sheets for battery separators.

Taiwania. A large tree used for pulp in Taiwan has been referred to in a trade note as "hemlock" but more likely is *Taiwania cryptomeroides*.

Cupressaceae

Thuja. Western red-cedar (*T. plicata*) is pulped by the sulfate process in the Pacific Northwest region.

Araucariaceae

Agathis. Queensland kauri (*A. palmerstoni* and *microstachya*) is pulped in small amounts.

Araucaria. Paraná pine (*A. angustifolia*) is pulped by the sulfite process in Brazil and northern Argentina, and for groundwood in Brazil. Hoop pine (*A. cunninghamii*) and bunya pine (*A. bidwilli*) are pulped in small amounts in Australia.

ANGIOSPERMAE

Monocotyledonae

PANDANALES

Typhaceae

Typha. The down of the fruit of the common cattail (*T. latifolia*) is used for insulation purposes and may possibly enter the industry as a waste material.

GRAMINALES

Gramineae (Poacoideae)

Stipa. Esparto is obtained from *S. tenacissima* in North Africa and Spain; also from a related grass, *Lygeum spar-*

tum. The grass is pulped primarily in the United Kingdom, but also in France, Italy, Spain, and quite recently in Algeria.

Avena. Straw from the common oat (*A. sativa*) is pulped, principally in Europe.

Phragmites. Danube reed (*P. communis*) is pulped in Italy and Rumania, and possibly in other regions.

Arundo. The giant reed (*A. donax*) serves as a source of pulp in Italy and Argentina, and possibly in other areas.

Hordeum. Straw from the cultivated barley (*H. sativum*) is pulped, principally in Europe.

Triticum. Straw from common wheat (*T. vulgare*) is pulped in many countries, especially Holland, Italy, Germany, United Kingdom, United States, Argentina, Uruguay, Hungary, Algeria, Portugal, Spain, Turkey, possibly in others. About a half-million tons of straw pulp, chiefly wheat, are produced in this country, but little, if any, of this pulp is bleached and used for high-grade papers.

Secale. Straw from cultivated rye (*S. cereale*) is pulped, principally in central Europe.

Oryza. Straw from cultivated rice (*O. sativa*) is pulped in China, Indonesia, Argentina, Italy, Brazil, United States, Spain, Egypt and possibly other regions.

Cymbopogon. Lemon grass (*C. citratus*) residue after oil extraction is pulped and formed into board in Guatemala.

Zea. Maize, or Indian corn (*Z. mais*), has been pulped for board purposes in the United States but apparently is no longer utilized.

Saccharum. There has been considerable research and discussion on the use of sugar cane bagasse (*S. officinarum*) as a source of pulp for various grades of paper. For many years a board known as Celotex has been manufactured, in part at least, from washed bagasse. Bagasse has been pulped in widely scattered areas by several processes. Among these areas can be listed Argentina, Brazil, China, Colombia, Cuba, Hawaii, India, Mexico, Peru, Philippine Islands, Puerto Rico, South Africa, Taiwan and the United States.

Sorghum. The cane from African corn (*S. vulgare*) has been proposed for pulping.

Eulaliopsis. Sabai grass (*E. binata*) is one of the primary raw materials for the paper industry in India.

Gramineae (Panicoideae)

Panicum. It may be that millet (*P. miliaceum*) is pulped in China.

Gramineae (Bambuseae)

There are approximately 1000 species and varieties of bamboo, of which some are quite suitable for pulping. Certain species are used for pulp in India, China, Pakistan, Thailand and Burma. Species known to be used for this purpose are listed here.

Bambusa. One of the most commonly processed is daba or kanta (*B. arundinacea*). A related species, *B. tulda*, is also used in India. Another is balki (*B. balcooa*).

Dendrocalamus. Some species of this genus which are pulped in India are *D. strictus* (salia), *D. hamiltonii* and *D. longispathes*.

Melocanna. Muli or mitenga (*M. bambusoides*) is pulped in India and Pakistan.

Pseudostachyum. *P. polymorphum* is pulped in India.

Teinostachyum. *T. dulloa* is pulped in India.

Thyrostachys. *T. siamensis* is pulped in Thailand.

Cyperaceae

Cyperus. For more than 30 centuries papyrus was made from the pith of *C. papyrus*. Its manufacture practically ceased near the close of the tenth century. The sedge is being used locally in Uganda for board.

XYRIDALES

Bromeliaceae

Tillandsia. Spanish moss (*T. usneoides*) is used for insulation and may find its way inadvertently as a waste into the paper industry.

Ananas. The leaf of the pineapple plant (*A. sativa*) contains a fiber which is extracted in various tropical countries for textile purposes. As a waste it may enter the paper industry. The very narrow diameter of the ultimate fiber may be of intrinsic value in certain specialty grades.

Aechemae. Pita floja is obtained from *A. magdalenae*.

Neoglaziovia. Fiber from the leaf of caroa (*N. variegata*) is pulped in Brazil and used in lightweight papers. It has also been used for certain molded products.

LILIALES

Liliaceae

Phormium. The leaf of *P. tenax* (unfortunately called by the misnomer "New Zealand flax" or "hemp") contains a fiber which is used for textiles and cordage, especially in its native land. The fiber enters the paper industry principally as a cordage waste but has been cultivated for pulping in Australia.

Sansevieria. Bowstring hemp is obtained from the leaf of *S. zeylanica*. It may enter the paper industry as cordage waste.

Yucca. Beargrass (*Y. elata*) has been pulped in the United States and used for specialty purposes.

Amaryllidaceae

Agave. At least two and possibly more members of this genus enter the paper industry as waste from the cordage industry. These species are sisal (*A. sisalana*) and henequen (*A. fourcroydes*). Other species which are possibilities are cantala or maguey (*A. cantala*) and pita or century plant (*A. americana*).

Furcraea. The species known variously as "Mauritius hemp", "piteira" and "aloe" (*F. gigantea*) enters the paper industry as old cordage or rough textile waste as do many of the so-called hard textile fibers.

SCITAMINALES

Musaceae

Musa. Abacá or Manila fiber (*M. textilis*) has been used for many years to make special grades. In Japan a lightweight sheet was made and exported to the United States for stencil paper, but 15 or 20 years ago domestic mills began to make their own paper from virgin fiber imported from the Philippine Islands. This fiber has also been used for tea bags. Manila fiber has gone into flour sacks and similar articles because it is flexible, strong and tough. Much of the fiber enters the industry from old cordage and rough textile waste to make the so-called rope papers. One mill in Costa Rica produces abaca pulp and blends it with kraft waste paper to produce multiwall bag paper.

Banana (*M. sapientum*) and plantain (*M. paradisiaca*) have a fiber which is not so long nor so strong as that of *Musa textilis*.

PALMALES

Palmaceae

Cocos. Certain species of palm, from which fibers are prepared, may get into the paper industry in small amounts as waste. An example is coir prepared from the husk of the coconut (*Cocos nucifera*) which has been widely used as door mats.

Dicotyledonae

MAGNOLIALES

Magnoliaceae

Magnolia. In the United States several members of this genus are pulped

in mixture with other hardwoods. These species are cucumbertree (*M. acuminata*), evergreen or southern magnolia (*M. grandiflora*), sweetbay (*M. virginiana*) and its southern variety, *australis*.

Liriodendron. Yellow-poplar (*L. tulipifera*) is pulped in the United States, chiefly with other hardwoods.

Lauraceae

Persea. Small quantities of redbay (*P. borbonia*) and swampbay (*P. palustris*) undoubtedly are pulped in mixture with other southern hardwoods.

Sassafras. Sassafras (*S. variifolium*) may occasionally be pulped with other species.

CISTALES

Datiscaceae

Tetrameles. Small amounts are used for chemical pulp in Thailand.

SALICALES

Salicaceae

Salix. Black willow (*S. nigra*) is pulped in small amounts in the United States. Presumably some willow is pulped in Argentina and Turkey.

Populus. Wood from various species and hybrids of this genus is used for pulpwood in several regions of the world, especially in the United States, Canada and Europe. Poplar culture is quite prevalent in Europe, and there are several experimental stations where hybrids are grown. Various hybrids have been studied in the United States during the last 30 years.

In North America the species used chiefly for pulping is quaking aspen (*P. tremuloides*). It is made into groundwood, sulfite, soda, kraft and neutral sulfite semi-chemical pulps. Other species used are largetooth aspen (*P. grandidentata*), balsam poplar (*P. tacamahaca*), eastern cottonwood (*P. deltoides*) and its variety *virginiana*, swamp cottonwood (*P. heterophylla*) and northern black cottonwood (*P. trichocarpa hastata*). In northern Europe the species pulped is aspen (*P. tremula*); in central and southern Europe, *P. alba, canadensis, italica* and *nigra*. Those in Japan are probably *P. sieboldii* and *P. maximowiczii*. Poplar is also pulped in Argentina and Turkey.

THEALES

Dipterocarpaceae

Shorea. The wood of the common Indian species, sal (*S. robusta*), is pulped in small amount.

Theaceae

Gordonia. Small amounts of loblolly-bay (*G. lasianthus*) are probably used in mixture with other southern hardwoods.

ROSALES

Platanaceae

Platanus. Small amounts of sycamore (*P. occidentalis*) may find use with other central hardwoods.

Rosaceae

Prunus. Wild black cherry (*P. serotina*) is pulped occasionally by the alkaline process and perhaps by neutral sulfite semi-chemical.

Mimosaceae

Acacia. Apparently black wattle (*A. decurrens*), which has a bark rich in tannins, is being pulped in South Africa.

Leguminosae

Crotalaria. The bast fiber of sunn (*C. juncea*) and possibly of other species enters the industry for rope papers from used cordage and rough textile waste.

Glycyrrhiza. Extracted licorice roots (*G. glabra*) have been used in board manufacture.

HAMAMELIDALES

Hamamelidaceae

Liquidambar. Sweetgum, or redgum (*L. styraciflua*), is generally used as a pulpwood in the South.

THYMELAEALES

Thymelaeaceae

Daphne. The bast fiber of some oriental species (*D. cannabina, involucra, pendula*) is used locally (Nepal) in handmade papers.

Edgeworthia. The bast fiber from mitsumata (*E. papyrifera*) is used in Japan. The shrub is cultivated to obtain the bast fiber.

Wikstroemia. The bast fiber of gampi (*W. canascens*) is used in Japan. The fiber is similar to that of mitsumata but is obtained only from wild plants. *W. viridiflora* appears in handmade papers in Viet Nam.

MYRTALES

Nyssaceae

Nyssa. Several species, commonly called "gums", constitute the major portion of the pulp hardwoods in the South. The principal species are black tupelo, or blackgum (*N. sylvatica*), and water tupelo, or tupelo gum (*N. aquatica*). Swamp tupelo, or swamp blackgum (*N. sylvatica biflora*), is also used, and probably some bolts of sour tupelo, or Ogeche lime (*N. ogeche*), find their way into mills.

Myrtaceae

Eucalyptus. Several species, especially mountain ash (*E. regnans*) and messmate stringbark (*E. obliqua*), are pulped in Australia. Other species pulped are alpine ash (*E. gigantea*), manna gum (*E. viminales*), peppermint (*E. salicifolia*) and silvertop ash (*E. sieberiana*). Blue gum (*E. globulus*) is pulped in Portugal, Spain, Morocco and Chile. The same species is used in the manufacture of roofing felts in Southern California. Saligna gum (*E. saligna*) is used in Brazil and South Africa. Forest red gum (*E. umbellata*) is also used in Brazil and river red gum (*E. camaldulensis*) in Italy.

URTICALES

Ulmaceae

Ulmus. The American, or white, elm (*U. americana*) has been used, particularly as feltwood for the manufacture of fiber for roofing felt.

Cannabinaceae

Cannabis. The bast fiber obtained from common hemp (*C. sativa*) has found its way into many types of paper, especially rope papers, for many years in many countries. It was one of several bast fibers used in the early days of papermaking. Most of the fiber enters the industry as textile or cordage waste.

Humulus. The bast fiber of common hop vine (*H. lupulus*) has appeared in paper in central Europe during war periods.

Moraceae

Broussonetia. The bast fiber of paper mulberry (*B. papyrifera*) has been in papermaking for centuries in the Far East. In Japan, where the fiber is known as "kozo", it is made by hand methods into papers with many ultimate uses. The tapa cloth of the Pacific Island natives is made from strips of the inner bark.

Cecropia. Imbauba (*Cecropia* sp.) is used in small amount for groundwood in Brazil.

Urticaceae

Urtica. Bast fiber from the common stinging nettle (*U. dioica*) of Europe has probably entered the rope paper industry as used cordage or fish nets.

Boehmeria. The fibers used by early Chinese papermakers are believed to have included the bast fibers of various

species of this genus, such as ramie (*B. nivea*) and its variety, *tenacissima*. To what extent these are of service today is not known.

FAGALES

Betulaceae

Carpinus. Hornbeam (*C. betulinus*) is probably pulped in Germany and other countries of central Europe.

Betula. The principal species of birch pulped in the United States and Canada is paper, or white, birch (*B. papyrifera*). Yellow birch (*B. lutea*) is also used and perhaps other species—gray birch (*B. populifolia*), sweet birch (*B. lenta*) and river birch (*B. nigra*). In the Scandinavian countries, *B. alba, pubescens* and *verrucosa* are pulped.

Alnus. Red alder (*A. rubra*) is pulped in the Pacific Northwest. European black alder (*A. glutinosa*) is probably pulped in Germany.

Fagaceae

Fagus. European beech (*F. silvatica*) is used considerably for pulp in central Europe, especially for dissolving pulp. A small amount of American beech (*F. grandifolia*) is pulped in this country.

Castanea. American chestnut (*C. dentata*) has been pulped for more than a quarter of a century. Both the unextracted wood and chips which have been leached to remove tannins have been used. This was probably the first species in commercial semi-chemical pulps. In Europe, especially in France and Italy, the wood of *C. sativa* is pulped.

Quercus. Chestnut, or rock, oak (*Q. montana*) and southern red oak (*Q. rubra*) are pulped in the United States, and probably other species of the red oak group. In France *Q. robur* is pulped. Perhaps other species of this large and far-spread genus are used for pulping.

MALVALES

Tiliaceae

Corchorus. The bast fibers of two Indian species, *C. capsularis* and *olitorius*, furnish the jute fiber of commerce. Jute fiber from jute butts, old sacks and bagging, and rough textile waste has been used in certain grades of paper for many years. In fact, one grade of board is still known as "jute", even though it no longer contains jute fiber.

Tilia. Basswood (*T. glabra*) is probably used in small amounts mixed with other hardwoods as is white basswood (*T. heterophylla*) and its variety, *michauxi*. It is not known whether linden (*T. europea*) enters paper manufacture in central Europe.

Malvaceae

Abutilon. The bast fibers of certain species may enter the paper industry from the cordage or textile industries.

Sida. The bast fibers of certain species may enter the paper industry from the cordage or textile industries.

Hibiscus. The bast fiber of *H. cannabinus*, known as "kenaf", "Ambari hemp" and "Bimlipatam jute", has been used locally in India for making paper. It has also served in the United States for rope paper manufacture and possibly in other countries, entering very likely as old cordage or rough textile waste. Perhaps other fibers from this genus, such as okra (*H. esculentus*) and roselle (*H. sabdariffa*) and its variety, *altissima*, are used in small quantities.

Urena. The bast fibers of aramina (*U. lobata* and its variety, *sinuata*) may enter the paper industry from the cordage or textile industries.

Adansonia. The bast fiber of the baobab tree (*A. digitata*) of Africa may enter the industry from the cordage or textile industries and is also extracted in Tanganyika.

Gossypium. The seed hair, both staple

and linters, of several species and varieties of cotton has been used extensively in the paper industry. Until only a little more than a century ago, cotton and linen fiber in the form of old rags were the primary sources of raw material for papermaking. Today the principal use of cotton fiber in the paper industry is for rag content bond and similar grades, although some old rags get into roofing felts. The source of supply is old rags or cuttings, although linters are being used to some extent. In America the main species is American Upland (*G. hirsutum*). Several other countries, especially in Europe, make fine grades of paper from cotton fiber, including filter paper. The bast fiber can be used, and several investigators have experimented with pulping of the whole stalk. It is not known whether this bast fiber is presently being processed.

Bombacaceae

Bombax. Small amount goes into chemical pulp in Thailand.

Ceiba. The floss of kapok (*C. pentandra*) enters certain grades from waste sources.

EUPHORBIALES

Euphorbiaceae

Ricinus. The bast fiber of the castor bean (*R. communis*) has been suggested as a fiber source but apparently has not yet gone into such service.

RUTALES

Anacardiaceae

Spondias. Small amount for chemical pulp in Thailand.

Simarubaceae

Simaruba. Small amount of marupa (*S. amara*) for groundwood in Brazil.

Ailanthus. Tree-of-heaven (*A. glandulosa*) is used occasionally with other hardwoods in this country, and is pulped also in Japan.

Rutaceae

Zanthoxylum. Small amount of temanqueira (*Z. rhoifolia*) in groundwood in Brazil.

JUGLANDALES

Juglandaceae

Juglans. Small amounts of butternut (*J. cinerea*) are pulped in mixture with other central hardwoods in the United States.

Carya. Some hickory or pecan (*Carya* sp.) undoubtedly enters the American industry, mixed with other central hardwoods.

SAPINDALES

Sapindaceae

Aesculus. Yellow buckeye (*A. octandra*) and its smaller associate, Ohio buckeye (*A. glabra*), are pulped in the United States. Perhaps common horse chestnut (*A. hippocastanum*) is used in southeastern Europe.

Aceraceae

Acer. Wood of sugar maple (*A. saccharum*), black maple (*A. nigrum*), silver maple (*A. saccharinum*) and red maple (*A. rubrum*) is pulped in the United States and probably in Canada. Other species, among them box elder (*A. negundo*), bigleaf maple (*A. macrophyllum*) and sycamore maple (*A. pseudoplatanus*), are probably pulped occasionally in mixture with other hardwoods.

Vochysiaceae

Vochysia. Small amount of quaruba (*Vochysia* sp.) in groundwood in Brazil.

GERANIALES

Linaceae

Linum. The bast fiber of common flax (*L. usitatissimum*) has been in paper-

making for centuries, if not by the ancient Chinese, then certainly by the Arabs. This fiber entered the paper industry for many years only in the form of old rags or textile waste, but recently the "straw" from linseed flax has been pulped after passing through breaker rolls. The resulting pulp contains not only bast fiber but shives or hurds (woody cells of the stalk). The thin papers are used primarily for cigaret tissue but also for condenser tissue. The bast fiber alone goes into currency, rag content bond, etc. It is used in France, Germany, Italy, Netherlands, United Kingdom, the United States, Canada and probably other countries.

LOGANIALES

Oleaceae

Fraxinus. Small amounts of white ash (*F. americana*), black ash (*F. nigra*) and probably other species enter mills with mixed hardwoods in the United States. Whether European ash (*F. excelsior*) is pulped is not known.

Asclepiadaceae

Asclepias. The floss of common milkweed (*A. syriaca*) and swamp milkweed (*A. incarnata*) has served as a kapok substitute and may enter the paper industry as a waste material. The bast fiber from the stalks has been studied and perhaps could find use in specialties.

POLEMONIALES

Bignoniaceae

Catalpa. Small amounts of catalpa (*C. speciosa* and *bignonioides*) are pulped with mixed hardwoods in the United States.

Jacaranda. Small amounts of parapara (*J. copaia*) is used for groundwood in Brazil.

Solanaceae

Solanum. Bast fiber from the stalk of the common potato plant (*S. tuberosum*) has been studied extensively and may have been used in central Europe during emergencies.

UMBELLALES

Araliaceae

Didymopanax. Small amount of morototo (*D. morototoni*) is used for groundwood in Brazil.

Fatsia. This genus includes the Taiwan plant (*F. papyriferae*), from whose pith "rice paper" is made. The pith is cut spirally with a sharp knife and the strips laid side by side, slightly overlapping. This procedure does not produce paper by our present-day definition of the term but gives a sheet somewhat similar to papyrus.

Bibliography

Innumerable references to studies on fibrous materials for papermaking have appeared in the technical literature. So have many notes on various fibers used commercially in various parts of the world. It would be impossible to list the articles consulted during or prior to the writing of this brief article. Instead, the attention of those interested is called to the following bibliographic material.

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Utilization Abstracts

Cattails. The four species of cattail native to the United States have long been utilized in handicraft enterprises but have not yet undergone extensive commercial exploitation, despite potentialities in that direction. Much of the estimated 140,000 square miles of swamp land in this country is dominated by these plants.

The American Indian made floor mats from the leaves, and used the leaves and leaf sheaths as caulking material; today several large companies manufacture rush seats for chairs from the leaves, and nearly all water-tight wooden barrels are caulked with leaf sheaths of one of the species, *Typha glauca*.

Three parts of the plants have been used as food—the pollen, to prepare cake or bread, two dozen "tails" yielding sufficient flour for a small cake; the rhizomes, roasted, raw or dried and ground into a meal; and the young shoots, eaten by the American Indian and the Cossacks of the Don Valley.

Modern attempts to exploit cattail in France, Germany and the U.S.A. have been concerned with utilizing the plants as substitutes for cotton, wool and jute; in the manufacture of paper and ethyl alcohol; and as a source of buoyant material, the fluff, to be used in life jackets and as sound-proofing and heat-insulating material.

The seeds contain about 18% oil, some 70% of which is linolenic acid. It might be employed as a drying oil and possibly as an edible oil. The potential annual yield of approximately half a billion pounds of cattail spikes in the United States, could furnish two hundred million pounds of seed which, in turn, could supply 34,000,000 pounds of oil and 166,000,000 pounds of extracted meal.

Lack of mechanical means of harvest and the all-important economic factors, which determine the feasibility of developing so many new plant products, have so far delayed commercial exploitation of these prolific plants. (L. C. Marsh and E. Reed, *Gard. Jour. N. Y. Bot. Gard. 5(4): 114. 1955; Chemurgic Digest 14(3): 9. 1955*).

Essential Oils. World production of essential oils according to plant families and genera, in 1947–48 was:

	Tonnes
Gymnosperms	
Coniferae (fir, pine)	250,000
(cedar)	200
Angiosperms	
Monocotyledons	
Gramineae (citronella, lemongrass)	4,200
Dicotyledons	
Lauraceae (camphor, cinnamon, rosewood, sassafras)	5,400
Labiatae (lavender, peppermint)	3,500
Rutaceae (citrus)	1,900
Myrtaceae (eucalyptus)	1,800
Magnoliaceae (star anise)	500
Umbelliferae (anise, coriander)	300
Geraniaceae (geranium)	130
Anonaceae (cananga, ylang ylang)	65

(W. Treibs, *Perf. & Ess. Oil Rev. 46(7): 222. 1955*).

Otto of Roses. This perfume, obtained from *Rosa damascena* and *R. alba*, is an important product of Bulgaria where it is steam distilled from the blossoms. Formerly produced in primitive stills of 120-liter daily capacity, it is now produced in installations of 5,000-liter output. (N. Nokolov, *Am. Perf. & Ess. Oil Rev. 66(1): 23, 24. 1955*).

Collection, Preservation and Utilization of Indigenous Strains of Maize

The seed of more than 12,000 variations of Indian corn have been collected from many areas in the Western Hemisphere, and are preserved at regional centers to provide genetic factors in the future breeding of agronomically improved, disease-resistant and higher yielding varieties.

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When the Americas were discovered at the end of the 15th century, corn (*Zea mays* L.), or maize, a crop new to Europeans and found to be indigenous to all of the Western Hemisphere, was being widely grown by the natives in many varieties. Its presence in the tombs of the Incas and in caves of Peru and other countries is evidence of its antiquity. For generation after generation Indian tribes maintained their own strains. Under the changing conditions of more recent years these old native strains have been gradually disappearing in many areas, but less in Latin American countries. There they are now being replaced by improved open-pollinated strains and to some extent by hybrids. New hybrid strains usually have a higher yield per acre, as well as other desirable characteristics. In the United States hybrid corns now occupy about 90 percent of the total corn acreage. In other countries new hybrids are being developed and distributed.

Original Strains of Maize

Native strains, the original source of improved varieties, may be the product of hundreds or thousands of years of evolution under domestication. They represent one of the irreplaceable agricultural resources of this hemisphere. Their extinction would deprive the areas, where they are now indigenous, of genetic material of value in future programs of improvement and also deprive the rest of the world of genes of great potential importance. The indigenous races and early pioneer open-pollinated strains of corn may include genes producing disease resistance, high yield and possibly other desirable economic traits, among them high food and feed qualities.

The Maize Committee

In order to prevent extinction of the desirable genes, a Committee on Preservation of Indigenous Strains of Maize was formed in the National Academy of Sciences–National Research Council to sponsor a project that would collect, preserve and study for future use as many varieties of native and pioneer corn as possible.

The committee is composed of leading corn breeders, geneticists, botanists and administrators concerned with the agricultural programs. The present roster is as follows:*

[1] Executive Secretary, Committee on Preservation of Indigenous Strains of Maize of the Agricultural Board, Division of Biology and Agriculture.

* Former members were: L. J. Stadler, John O. Brew, and Hugh C. Cutler.

Ralph E. Cleland, *Chairman*, Head of Department of Botany and Dean of the Graduate School, Indiana University, Bloomington, Indiana
J. Allen Clark, *Executive Secretary*, Division of Biology and Agriculture, National Research Council, Washington, D. C.
Edgar Anderson, Director, Missouri Botanical Gardens, St. Louis, Missouri
William L. Brown, Geneticist, Department of Plant Breeding, Pioneer Hi-Bred Corn Company, Johnston, Iowa
C. O. Erlanson, Head of Plant Introduction Section, U. S. Department of Agriculture, Plant Industry Station, Beltsville, Maryland
Claud Horn, Foreign Agricultural Service, U. S. Department of Agriculture, Washington, D. C.
Merle T. Jenkins, Principal Agronomist, In charge Corn Investigations, U. S. Department of Agriculture, Plant Industry Station, Beltsville, Maryland
Paul C. Mangelsdorf, Director, Botanical Museum, Harvard University, Cambridge, Massachusetts
G. H. Stringfield, Senior Agronomist, Ohio Agricultural Experiment Station, Wooster, Ohio
Paul A. Weatherwax, Professor of Botany, Indiana University, Bloomington, Indiana

This Committee, in cooperation with the Rockefeller Foundation, has established Seed Centers in Mexico and Colombia at the Foundation's Agricultural Experiment Stations; it has received the cooperation of the University of Sao Paulo in the establishment of a Seed Center at Piracicaba in Brazil, and of the U. S. Department of Agriculture in the maintenance of a Seed Center in the United States. Collections originating in the United States and Canada are in active storage at the cooperative Regional Plant Introduction Station at Ames, Iowa. All requests for seed from the different collections should be made to the Directors of the Latin American Centers or to the Plant Introduction Section of the U. S. Department of Agriculture, Beltsville, Maryland.

Seed Center Directors

The names and addresses of the Directors of the Seed Centers are:

Mexican and Central American Areas
Dr. E. J. Wellhausen
The Rockefeller Foundation
Calle Londres 45
Mexico 6, D. F. Mexico

Colombian-Andean Area
Dr. L. M. Roberts
The Rockefeller Foundation
Apartado aero 58-13
Bogota, Colombia

Brazilian-Eastern South American Area
Dr. F. G. Brieger
Departamento de Genetica
Escola Superior of Agriculture "Luiz Queiroz"
Piracicaba, S. P. Brasil

United States and Canada
Mr. C. O. Erlanson, In charge
Section of Plant Introduction
U. S. Department of Agriculture
Plant Industry Station
Beltsville, Maryland

Collections of Original Strains

Throughout Latin America and other parts of the Western Hemisphere, several thousand collections of indigenous Indian and pioneer open-pollinated strains of maize have been assembled at these Centers. This collecting began in 1943 when The Rockefeller Foundation, in cooperation with the Mexican Ministry of Agriculture, began a program of practical maize improvement. It became evident at that time that a survey of the native maize varieties was needed. Varieties were collected from all parts of Mexico and, in controlled experiments, were compared for yield, disease resistance and other characteristics of agricultural importance. As the collections grew and the extraordinary diversity of maize in Mexico was revealed, the need for a taxonomic classification of the bewildering multiplicity of varieties became apparent. Botanical, genetic and cytological studies to supplement the agronomic investigation were begun. To make collections more complete, special efforts were made to obtain from remote localities most of the commonly grown varieties or strains, regardless of their

apparent agronomic value. This collection became known as the "germ plasm seed bank". These studies led to a classification and description of the principal races which was first published in Spanish and later in English (1).

In the United States, the Section of Plant Introduction of the U. S. Department of Agriculture has for many years collected corns from all parts of the world. With the rapid increase in the growing of hybrid corns in the United States, plus the apparent value of the Mexican collections, the importance of keeping these collections viable and of preserving the pioneer open-pollinated corns of the United States was obvious. Federal funds were made available to the States of Kansas, Missouri, Nebraska and North Dakota through Cooperative Regional Project NC-7 to bring together such pioneer varieties as existed in those States. This material is now largely held at the Regional Plant Introduction Station, Ames, Iowa.

The Committee for the Preservation of Indigenous Strains of Maize studied the problem in the whole Western Hemisphere. It obtained financial support from the United States Department of State, administered through the Office of Foreign Agricultural Relations, Department of Agriculture, and later through the Institute of Inter-American Affairs. Under an agreement with the Technical Cooperation Administration (Contract No. SEC 14029, dated June 28, 1951), the Committee has been sponsoring the collecting and preservation of as many varieties of native and pioneer corn as possible. One of its members collected and studied maize strains of the Caribbean area (1).

Cooperation

The NAS-NRC has had no formal agreements with governments of Latin-American countries, but the project has had enthusiastic support, both financial and in personnel, of a number of governments and of their technical representatives. In order to give public credit, a partial list of those who have assisted in this collecting work in the Western Hemisphere follows. Without their work in field, laboratory and office, no collections would have been made.

Mexican and Central American Areas

Mexico Seed Center at Chapingo
Mexico
Mexico City—E. J. Wellhausen, Director. In charge of The Rockefeller Foundation Agricultural Program in Mexico
Sterling Wortman, Corn Project Leader and Co-Director of Seed Center
Chapingo— Hernandez Corzo, in charge of the storage and records
Lauro Bucio, in charge of collecting
Caribbean Area—William L. Brown, Maize Committee member
Cuba—C. G. delValle
Haiti—Claude Preval, Leon Pierre Louis
Martinique—George Mottard
Puerto Rico—J. Velez Fortuno
Trinidad—L. Johnson
Central America—Alfredo Carballo, in charge of collecting
Costa Rica—Mario Guittierez
El Salvador—Floyd Olive
Guatemala—Francis LeBeau
Honduras—Albert Miller
Nicaragua—S. C. Litzenberger

Colombian-Andean Area

Colombian Seed Center at Medellin
Colombia
Bogota— L. M. Roberts, Director. In charge of The Rockefeller Foundation Agricultural Program in Colombia
Emilio Yepes, Corn Project Leader
Medellin— Ulysses J. Grant, Co-Director, in charge of Station
Donald L. Smith, Corn Project Leader
Victor Patiño, in charge of collecting
P. E. Daza, in charge of storage and records
Palmira— Roberto Astralaga
Monteria—Climaco Cassalett

Ecuador—Gaston Noroña, Luis A. Flor, Victor H. Alride, Napoleon Valdivieso, Ricardo Gellegos, S. Manuel Giler Honorio Moreno
Peru—Alexander Grobman, Botanico Octovio Velarde
Bolivia—Francisco Pulgarr, Alfonso Corrate V.
Chile—Guillermo Crespo, Martin Gardenas, Leandro Rojo F., Alberto Ruiz S.
Venezuela—Casa Briceno, Herman Oreopeza, Pedro Obregon

Brazilian-Eastern South American Area

Brazilian Seed Center at Piracicaba
Brazil
Piracicaba—F. G. Brieger, Director. In charge of Department of Genetics, College of Agriculture, University of Sao Paulo
J. T. Cargel, Deputy Director of the Center
E. Paterniani, Assistant to the Center
W. E. Karr, Collecting
Campinas—Glauco Viegas, Corn Breeding
Paraguay—Charles Breitenbach
Uruguay—Gustavo Fisher, V. Gheorghiano
Argentina—J. M. Andres, Jose Vallega

United States and Canada

United States—U. S. Department of Agriculture
Washington, D. C.—Claud Horn, Foreign Agricultural Service
Beltsville, Maryland—C. O. Erlanson, Section of Plant Introduction
Glenn Dale, Maryland—John L. Creech
Ames, Iowa—Max M. Hoover

Cooperators

St. Louis, Missouri—Hugh C. Cutler, Collection in the Southwest
Johnston, Iowa—William L. Brown, Central Area
Bismarck, North Dakota—George F. Will, Northern Area
Canada—University of Manitoba
Winnipeg—S. B. Helgason, Corn Project Leader

The material collected is a part of the work of these governments and their technical staff aided by local assistants. The training of local personnel is one of the objectives of this project, and already a considerable number of young Latin Americans have received invaluable training in the technique of plant exploration, record keeping, agronomic experiments, botanical description and genetic analysis. Thus they have gained experience in research methods which makes them more competent and especially useful to use the material collected for conducting improvement breeding programs in their own countries.

Collections

The collecting extended over a three-year period and came to an end arbitrarily set at June 30, 1954. Samples collected in the different countries were sent to the Centers where they were recorded and numbered. Many of the original ears were photographed and museum specimens kept. Grain was shelled, and moisture and germination tests were made before storage. Some samples were discarded, others had to be rejuvenated before storage. All samples stored were listed with the Center numbers, country, state, town or township of origin, local name, altitude, latitude, longitude, type, seed color, maturity, rainfall, and culture indicated.

Each of these factors has an important bearing on the identification, adaptation and plans for further field study necessary for classification of the more important varieties and races. For example, altitude has a most important effect upon corn-growing. The highest location found for corn-growing was by collectors of the Colombia Center above Lake Titicaca which lies between Peru and Bolivia at 12,500 feet. The lists reveal many other important factors and types of corn available.

These lists were sent from the Centers to the National Research Council, where NRC numbers were assigned as the lists were received. The lists were mimeographed, and processed reports entitled "Collections of Original Strains of Corn

I and II" (3), were made available to FOA and other government officials, to cooperators and interested corn workers on request.

The NRC numbers assigned to the Center lists and listed number of collections for each are as shown in Table I.

TABLE I

NRC Nos.	Centers and Number of Collections			
	Mexico	Colombia	Brazil	U.S.
1–925	....	925	....	....
926–1,171	....	246	....	....
1,172–1,998	827	....	....	....
1,999–2,611	....	....	613	....
2,612–4,534	1,923	....	....	....
4,535–5,140	....	606	....	....
5,141–5,386	....	....	....	246
5,387–6,987	1,601	....	....	....
6,988–7,155	....	....	168	....
7,156–8,442	....	1,286	....	....
8,443–9,715	....	....	1,273	....
9,716–10,596	....	881	....	....
10,597–10,922	....	....	326	....
Total 10,922	4,351	3,945	2,380	246

The first report of this collecting work, more extensive than the present brief article, was published by the National Research Council (2).

The number of collections received at the Centers has sometimes exceeded that listed. Some of these not already listed may be rejuvenated and listed later, while others may not have been viable or for other reasons were discarded. In order to show the magnitude of the collecting task, both the Reported and Listed numbers of collections from each Seed Center and country are listed.

The largest number of listed collections, 4,351, are at the Mexican Center; from Mexico, 2,750; from Guatemala, 1,054; and less numbers from six other Central American countries and from seven Caribbean Islands.

At the Colombian Center are 3,945 listed collections, 1,360 from Colombia and other large numbers from five other western South American countries.

The Brazilian Center has listed 2,380 collections, while over 100 more are reported and may be listed later.

The following shows the reported and listed number of collections from each Center and country.

	Number of Collections	
	Reported	Listed
Mexican Center		
Mexico	2,761	2,750
Costa Rica	33	33
El Salvador	40	40
Guatemala	1,054	1,054
British Honduras	14	14
Honduras	30	30
Nicaragua	49	49
Panama	25	25
Cuba	70	70
Dominican Republic	235	235
Haiti	15	15
Virgin Islands	4	4
Jamaica	4	4
Martinique	10	10
Trinidad	18	18
Total	4,362	4,351
Colombian Center		
Colombia	1,666	1,360
Venezuela	586	586
Peru	735	646
Ecuador	555	555
Bolivia (western)	702	702
Chile	100	83
Others	....	13
Total	4,344	3,945
Brazilian Center		
Brazil	2,029	1,928
French Guiana	20	11
British Guiana	13	13
Surinam	16	11
Bolivia (eastern)	16	16
Paraguay	107	107
Uruguay	158	148
Argentina	136	133
Others	13	13
Total	2,508	2,380
United States Center		
United States	250	215
Canada	31	31
Total	281	246
Grand Total	11,353	10,922

In the Committee's program, only 246 listed collections went to storage at the United States Center; 31 of these came from Canada. However, there are also other collections in the United States. These include 833 introductions from 35 countries that have been collected and kept viable by the Section of Plant Introduction, USDA, and 163 samples by the Section of Cereal Crops and Diseases, USDA. The latter include 140 strains from Indians of the United States, 12 from Mexico, 3 from Guatemala and 8 from South America. Collections of a more local nature are in storage at several of the State Agricultural Experiment Stations. In all, this should make up a "World Collection" of more than 12,000 strains.

Preservation

Seed stored under ordinary conditions will not remain viable more than five years, but it will last for a much longer period under the conditions established by the Committee and provided at the Seed Centers. The seed is dried to 8–10% moisture content, sealed in airtight bottles, and stored at 25° to 30° F. Under these conditions it is thought that the seed will stay viable for ten to 25 years. Germination tests will be made from time to time and the strains rejuvenated when necessary.

Seed cabinets for storage of four-ounce seed samples of the original collection were furnished the Latin-American Centers through the Committee of the National Research Council, while larger working samples are also used at some of the Centers. Refrigeration equipment was furnished the Brazilian Center by the Committee, while the Rockefeller Foundation supplied that at the Mexican and Colombian Centers. Collections held in the United States are stored through the cooperation of State and Federal agencies.

Utilization

This material, collected throughout the Americas, will undoubtedly be of great value in the development of higher yielding, agronomically improved and disease-resistant varieties of maize in other parts of the world. Introduction of corn into other parts of the world is a relatively recent matter. One reason for the rapid spread is the increasing industrial importance of corn products—waxes, oils, glue, pastes and various forms of starch.

The value of the world maize collection has already been demonstrated. Collections have been sent from the Centers to plant breeders in Kenya, Ethiopia, Poland, Indonesia and about 35 other countries. A corn rust disease, caused by *Puccinia polyspora*, recently became extremely serious in West Africa, reducing yields as much as 50%. It was found that certain strains collected in the Caribbean area were either resistant or highly tolerant to this disease. Consequently, 125 strains of maize collected from the Caribbean were sent to the agronomists of West Africa. By proper crossing techniques they can now transfer to their strains the valuable resistant genes.

These extensive collections are expected to reveal other important pathologic, agronomic and industrial characteristics, including many which are new or which have not been described or have not as yet been available. New sources of corn germ plasm have thus been made permanently available for plant breeders to develop varieties, not only giving high yields of grain, but also having higher contents of vitamins, minerals, proteins and other substances.

The current expansion of industry in Latin America is in part dependent on corn, the principal crop, and there the industrial use of different types of corn is rapidly increasing. A search for de-

sirable high (70 percent or higher) amylose starch content corns has been started on broad types of the NRC collections in the United States by the Northern Regional Research Laboratory at Peoria, Illinois.

Another important use of the collection is that of providing materials for basic genetic research on corn. Already two eminent geneticists have canvassed a large part of the collections, searching for new characters or genes to be employed in such research. Additional knowledge concerning these collections should lead to the continued screening of this material for these and other uses.

Future Plans

The NRC maize collections, made possible by the original TCA (now ICA) grant, The Rockefeller Foundation, the U. S. Department of Agriculture, the University of Sao Paulo and cooperating Latin American governments, are nearing completion. Further financial support is being received from the International Cooperation Administration for a second part of the program to enable careful study of the Latin American collections of the different governments at the Seed Centers. The Center Directors and corn project leaders will select as assistants promising local personnel for the growing and study of the material. In order to promote coordination and integration of the program it is proposed to send to each Center a member of the Committee, or other North American experts on corn. They will go over the work being done and assist in the study of these collections for their botanic, agronomic, pathologic and cytogenetic characteristics, classify key material and publish descriptions of the principal races. The composition or determination of the food, feed and industrial properties of the collections, varieties or races cannot be determined with these funds. However, they will be better known and made available to corn breeders and to industrial research workers as a result of the proposed studies and publications.

Summary

Native strains of corn may be the product of hundreds or thousands of years of evolution under domestication. To prevent extinction, a Committee on Preservation of Indigenous Strains of Maize was formed to sponsor a project that would collect and preserve as many varieties of native and pioneer corn as possible. This article summarizes the collecting work and plans for a study and classification of the principal races under a further grant from the International Cooperation Administration to the National Academy of Sciences–National Research Council.

Literature Cited

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